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PART I

Bioventing Pilot Test Work Plan for

PS-2, PS-1A, PS-1B, BUILDING 2034, BUILDING 2035

Fairchild Air Force Base, Washington

PART II

Draft Bioventing Pilot Test Interim Results Report for

PS-2, PS-1A, PS-1B, BUILDING 2034, BUILDING 2035

Fairchild Air Force Base, Washington

VOLUME 1 OF 2

Prepared for

Air Force Center for Environmental Excellence
Brooks AFB, Texas
and
Fairchild Air Force Base, Washington

June 1994

Prepared by

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PART I

Bioventing Pilot Test Work Plan for

PS-2, PS-1A, PS-1B, BUILDING 2034, BUILDING 2035 FAIRCHILD AIR FORCE BASE, WASHINGTON

Prepared for

Air Force Center for Environmental Excellence
Brooks AFB, Texas
and
Fairchild Air Force Base, Washington

June 1994

Prepared by

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for
PS-2, PS-1A, PS-1B, BUILDING 2034, BUILDING 2035 FAIRCHILD AFB, CALIFORNIA

1.0 INTRODUCTION

This Pilot Test Work Plan presents the scope of in situ bioventing pilot tests for treatment of fuel contaminated soils for five sites at Fairchild Air Force Base, Spokane County, Washington. Fairchild AFB is located approximately 12 miles west of Spokane, Washington.

1.1 Bioventing Pilot Test Organization

The bioventing pilot test which will be conducted at each of the five sites has three primary objectives. These are: 1) to assess the potential for supplying oxygen throughout the fuel hydrocarbon-contaminated soil zone, 2) to determine the rate at which indigenous microorganisms will degrade the fuel in the soil when stimulated by oxygen rich soil gas, and 3) to evaluate the potential for sustaining these rates of fuel biodegradation until the contamination is remediated below regulatory standards.

The bioventing pilot test at each site will be divided into two test events. An initial pilot test will determine the technical feasibility and important design parameters such as air permeability, radius of oxygen influence, fuel biodegradation rates, and potential air emissions (via soil gas escaping from the subsurface to the atmosphere during air injection). An extended (one-year) pilot test will determine the longer term application of this remedial technology to degrade hydrocarbons at each individual site. If bioventing proves to be applicable, pilot test data could be used to design and implement a bioventing remediation system. A significant amount of the fuel contamination should be biodegraded during the extended (one-year) pilot tests since the bioventing will take place within the most contaminated soils at each site.

Additional background information on the development and recent success of the bioventing technology is found in the document entitled "Test Plan and Technical Protocol for a Field Treatability Test for Bioventing" (Hinchee et al. 1992). This protocol document will also serve as the primary reference for the pilot test well designs and detailed procedures which will be used during the tests.

Much of the background information used in this Draft Bioventing Pilot Test Work Plan is derived from prior studies and reports which are listed in Section 8.0.

1.2 Fairchild AFB Background

Fairchild AFB is located approximately 12 miles west of Spokane, Washington and covers approximately 4,300 acres. The Base was established in 1942 as an Army repair

depot, but was transferred to the Strategic Air Command (SAC) and assigned to the Fifteenth Air Force in 1947. In June 1992, the Air Combat Command (ACC) was established within the Air Force and ACC assumed command of the Base. The Base is currently home to a detachment of the Washington Air National Guard (WANG), aircraft operational facilities, a weapons storage area, and a survival training school and employs approximately 5,000 civilian and military personnel.

Known past waste management practices with potential for contamination of the environment have included: petroleum, oils, and lubricant (POL) management; fire training exercises; solid waste disposal; industrial and aircraft operations; industrial wastewater treatment; and storm water drainage.

Numerous environmental investigations have been performed throughout Fairchild AFB as part of the U. S. Air Force (USAF) Installation Restoration Program (IRP). Possible sources of contamination at Fairchild AFB identified in prior studies are named based on site type and grouped according to priority. One of the five sites proposed for bioventing is a Priority One site: PS-2 (Petroleum Storage), which is part of Operable Unit 1 (OU-1), and includes flightline fuel operations. Two of the remaining four sites are within a Priority Two site, PS-1. The two bioventing sites within PS-1 have been designated PS-1A and PS-1B to distinguish them as two separate bioventing sites. The two remaining sites, Building 2034 and Building 2035, are not currently IRP sites. The five bioventing site locations are shown in Figure 1.1.

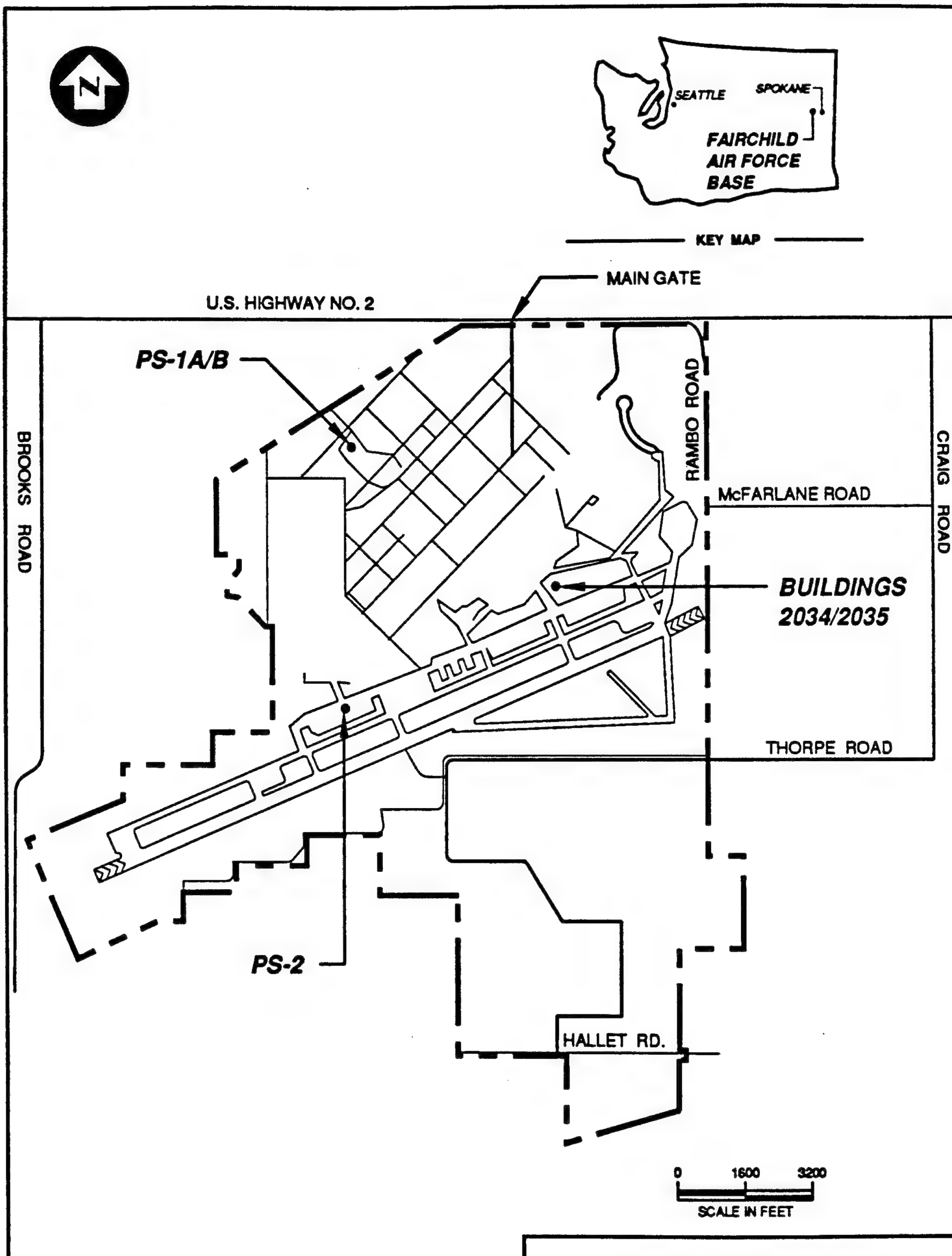
1.3 FAIRCHILD AFB GEOLOGY AND ENVIRONMENTAL SETTING

Fairchild AFB is situated within the Columbia Plateau geomorphic region, an area of low topographic relief in northeastern Washington. The topography is created by nearly flat-lying Tertiary basalt flows that were extruded over deformed Paleozoic and Precambrian metasedimentary rocks.

The base is underlain by soils derived from Quaternary floodplain, glacial and aeolian deposits, and weathered bedrock. The soils have been grouped by the U.S. Soil Conservation Service (1968) into eleven types ranging from silty clay loam to extremely rocky complex. The soils occur 20 to 40 inches deep with permeabilities that range from poorly drained (0.2 in/hr) to excessively drained soil (>10 in/hr).

The Quaternary deposits are comprised of fine-grained clays and silts with intercalated sandy silts, sandy clays and sandy gravels. These deposits range in thickness from 1 to 46 feet and often increase in gravel content as they approach the underlying basalt bedrock.

Underlying the Quaternary sediments is bedrock consisting of a sequence of nearly horizontal Tertiary basalt flows that are part of the Columbia River Basalt Group. Between the basalt flows are interbedded alluvial and lacustrine deposits of clay and fine-grained silts referred to collectively as the Latah Formation. These sediments were deposited in a changeable topography of lakes and streams created by intermittent episodes of lava flows during the Tertiary.



SITE LOCATIONS

FAIRCHILD AIR FORCE BASE, WASHINGTON

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The uppermost basalt, referred to as Basalt A, ranges in thickness from 166 feet in the western area of the base to 193 feet in the east. Basalt A is vesicular, moderately fractured, and weathered at the top, and is vesicular and fractured at the base and becomes massive and columnar with tight fractures toward the center. Interbed A of the Latah Formation underlies Basalt A and consists of laterally extensive claystone ranging in thickness from 8.5 to 10 feet with a reported thickness of 3 to 41 feet in the area east of the Base. Underlying Interbed A is Basalt B. Basalt B is porous and vesicular at the top and becomes massive and less vesicular with depth. The thickness of Basalt B is unknown; however, basalt flows within the Columbia Basalt group average about 300 feet.

Groundwater at the base is usually encountered at approximately 8 to 12 feet below ground surface (bgs) and occurs in both the Quaternary sediments and basalt bedrock. Groundwater in the Quaternary sediments is under unconfined to locally semiconfined conditions. Groundwater occurs in the basalt and sedimentary interbeds under confined to unconfined conditions. The layered basalt flows and sedimentary interbeds form a high degree of aquifer heterogeneity resulting in vertical and horizontal anisotropic conditions. Conduits of groundwater movement occur as both fractures and integranular connections. Pumping test data shows a good hydraulic connection between the Quaternary deposits and upper portion of Basalt A and together they are referred to as the overburden-shallow bedrock aquifer. This aquifer is poorly connected to a deeper bedrock aquifer encountered within 200 feet bgs. Average horizontal hydraulic conductivities in the Quaternary deposits, shallow bedrock basalt, and deep bedrock basalt are estimated at approximately 288, 0.74, and 0.38 ft/day, respectively.

Direction of regional groundwater flow is controlled by physiographic and structural controls, by the distribution of hydraulic conductivities, and by differences in head because of natural and artificial recharge and discharge. Groundwater in the overburden-shallow bedrock aquifer generally flows from west to east, with a slight downward vertical flow component. This west to east movement occurs, in part, in response to a slightly southeast dipping ground surface and underlying basalt bedrock surface. The average overall lateral flow gradient across the base is approximately 0.0045.

Fairchild AFB and the surrounding central interior plains of the Columbia Basin have a semi-arid climate characterized by warm, dry summers and cold, moist winters. The Base has a mean maximum daily temperature range from 31.4 degrees F in January to 83.6 degrees F in July and mean minimum daily temperature range from 19.2 degrees F in January to 55.4 degrees F in July. Average annual rainfall is approximately 17 inches per year and occurs primarily as snow from late fall to early spring.

2.0 SITE DESCRIPTIONS

The following sections provide a brief summary of the location, history, geology, and known contaminant distribution at each of the five sites where bioventing pilot testing will occur. Site locations are shown in Figure 1.1.

2.1 PS-2

2.1.1 Site Location and Description

PS-2 is a Priority One site located along the northern edge of the flightline in front of Buildings 1029, 1033, and 1037, which are flightline hangars. Five refueling/defueling pits (Pits 17 through Pit 21) are within the site boundary. The site is covered with asphalt and is partially beneath Ladder Taxiway No. 1. The site is in the Washington Air National Guard (WANG) portion of Fairchild AFB. The area of PS-2 proposed for bioventing is south of Buildings 1033 and 1029 near Pit 19 (Figure 2.1). Surface runoff flows to the storm sewer system also shown on Figure 2.1.

2.1.2 Site History

In 1984, the fuel tank at defueling/refueling Pit 18 (330 feet northeast of Pit 19) is known to have leaked up to 120 gallons of JP-4 fuel (Halliburton NUS 1993). In 1985, approximately 5,000 gallons of JP-4 were spilled when a fuel line flange cracked at Pit 21, located south of Building 1037. The spill overflowed the storm sewer system at the manhole in front of Building 1033. Although 4,000 gallons were estimated to have been recovered, the remaining 1,000 gallons of fuel were lost to the storm sewer system and surrounding soils. In 1989, evidence of floating product in groundwater was detected at the PS-2 site.

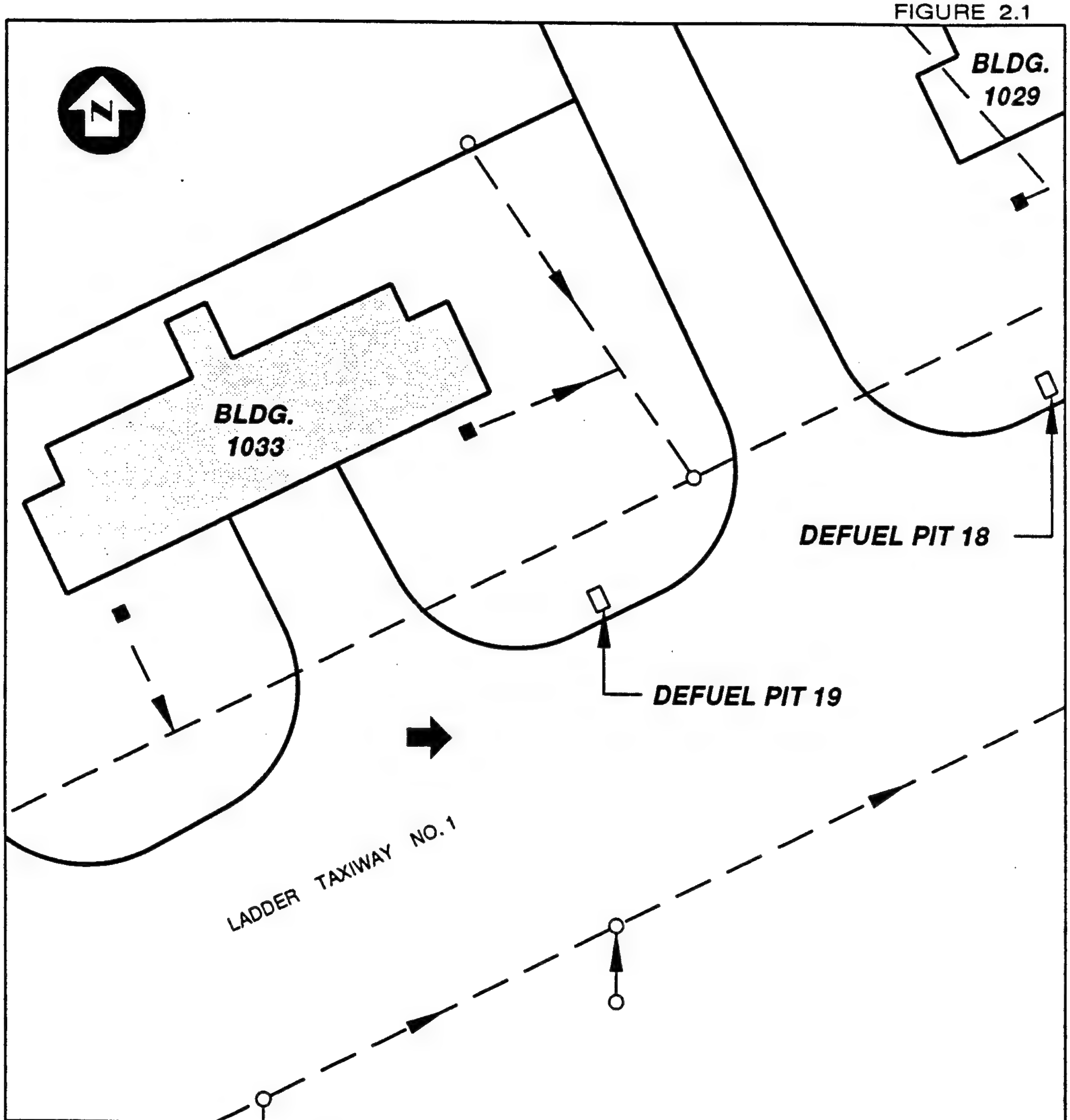
2.1.3 Site Geology

Figure 2.2 shows the location of soil borings and monitoring wells in the area proposed for bioventing. Geologic cross-section A-A', presented in Figure 2.3, is constructed from boring logs taken from borings 007 and 009 and well logs for monitoring wells MW-56 and MW-177. The cross-section is oriented along a generally south to north line through the site and exhibits a soil profile from the surface to a depth of approximately 13 feet.

A gravelly sand interval approximately 2 feet in thickness underlies the surface asphalt. Silty clays and clayey silts then predominate to approximately 5 feet bgs. Although no clay was recorded in the well log for MW-56, rich silt layers were noted. Silt and silty sand deposits continue to about 8 feet bgs. A gravel or sandy gravel interval of unknown total thickness underlies the sand and silty sand interval. Deeper borings in the vicinity of the site indicate the basalt bedrock layer (Basalt A) is at 15 to 24 feet bgs.

Groundwater was encountered at about 7.5 to 9 feet bgs according to the well logs, with approximately a one-foot seasonal variance in the water level. In April 1992, the water level in MW-177 was approximately 9 feet bgs. Groundwater flow is generally from northwest to southeast in the area of the proposed bioventing pilot test, although it varies locally across the entire PS-2 site. The hydraulic gradient is approximately 0.006

FIGURE 2.1



EXPLANATION

- MANHOLE
- STORM SEWER LINE
- OIL/WATER SEPARATOR
- APPROXIMATE DIRECTION OF GROUNDWATER FLOW

0 50 100
SCALE IN FEET

SOURCE: MODIFIED FROM HALLIBURTON NUS (1993)

SITE MAP
PS-2

FAIRCHILD AIR FORCE BASE, WASHINGTON

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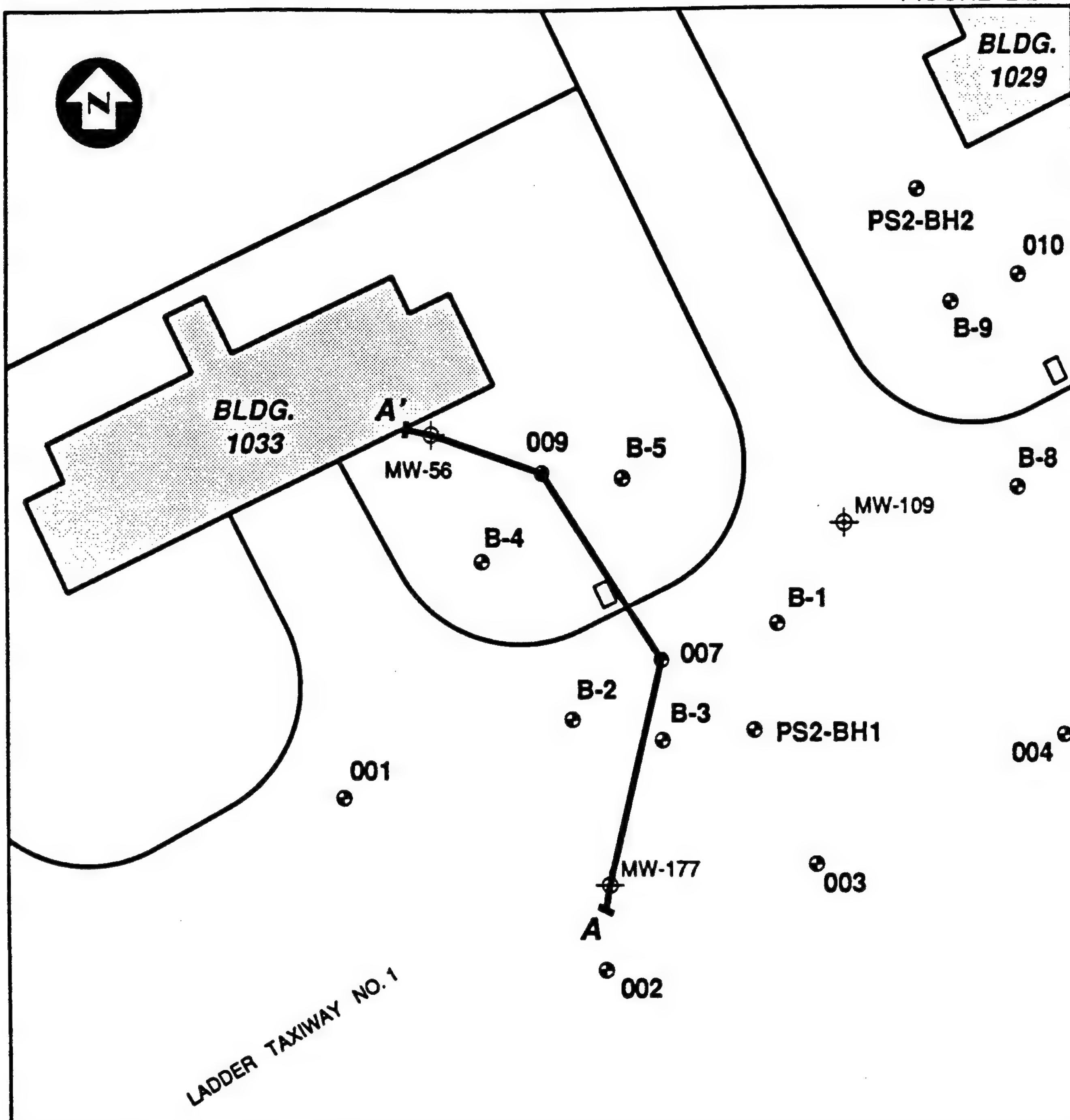
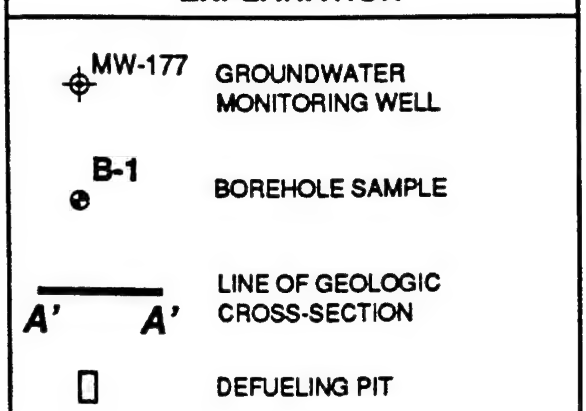
FIGURE 2.2



EXPLANATION



SOURCE: MODIFIED FROM HALLIBURTON NUS (1993)

SAMPLE AND MONITORING WELL LOCATIONS PS-2

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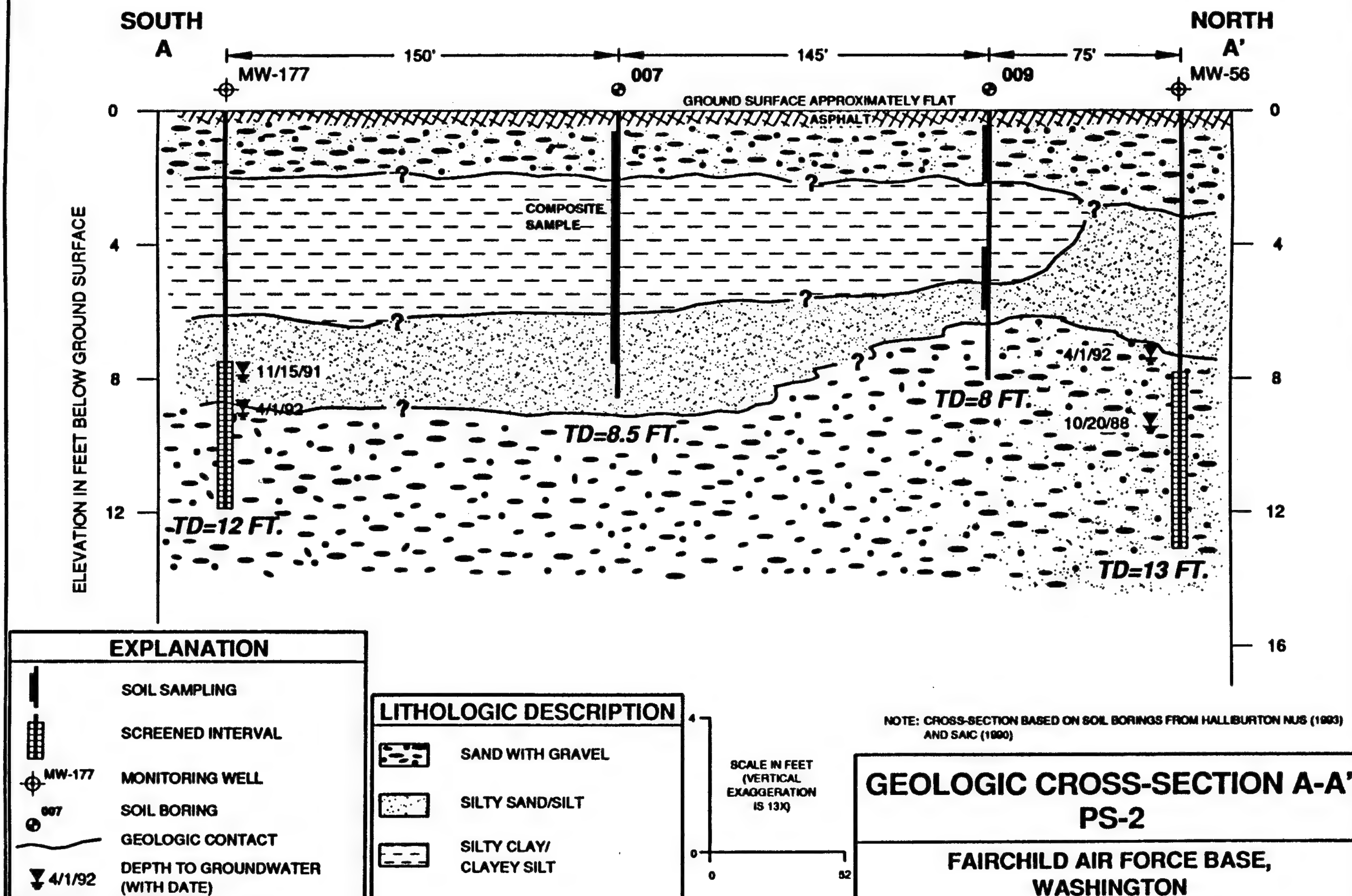


NOTE: CROSS-SECTION BASED ON SOIL BORINGS FROM HALLIBURTON NUS (1993) AND SAIC (1990)

GEOLOGIC CROSS-SECTION A-A'
PS-2

FAIRCHILD AIR FORCE BASE, WASHINGTON

ft/ft and a pumping test conducted at MW-56 estimated a hydraulic conductivity of 24 ft/day (Halliburton NUS, 1993).

2.1.4 Site Contaminants

Petroleum hydrocarbons and volatile organics have been detected in soils at the site. Soil samples were collected and analyzed for total recoverable petroleum hydrocarbons (TRPH) and volatile organics including benzene, toluene, ethylbenzene, and total xylenes (BTEX) during soil boring activities and monitoring well installation at the site. Analytical results for TRPH and BTEX for soil samples collected near Buildings 1033 and 1029 are shown in Table 2.1a.

These results indicate maximum levels of contamination near Pit 19. The maximum levels of contaminants found were 1,278 mg/kg TRPH (B-2), 2.4 mg/kg benzene (B-1), 9.4 mg/kg toluene (B-5), 7.5 mg/kg ethylbenzene (B-3), and 92.1 mg/kg total xylenes (B-5). TRPH levels greater than 1,000 mg/kg were found immediately southeast of Pit 19 in soil borings 007, B-2, and B-3. It is not known how deep residual fuel contamination exists in soils at the site since some of the deepest samples (10 to 11 feet bgs) had significant concentrations of fuel components. In addition to the results shown in Table 2.1a, semivolatile organics were analyzed for samples collected from 004, 007, and MW-56. Naphthalene was detected at 0.57 mg/kg (007) and 2-methylnaphthalene was detected at 1.3 mg/kg (007).

Contamination of groundwater has been documented in monitoring wells MW-109 and MW-177. Groundwater analytical results from sampling round 11 conducted in January 1992 are shown in Table 2.1b. Maximum levels reported were: 27,000 g/L TRPH, 240 g/L benzene, 520 g/L ethylbenzene, and 2,200 g/L total xylenes, all found in MW-177 (Halliburton NUS 1993). Floating product, 1.44 feet in thickness and black in color, was observed in MW-177 in April 1992.

Groundwater samples from MW-109 and MW-177 were also analyzed for semivolatile organic compounds (EPA 8270); however, no contaminants were detected.

2.2 PS-1 (PS-1A and PS-1B)

2.2.1 Site Location and Description

PS-1 is the bulk fuel storage tank farm, located in the northern part of the Base and is a Priority Two site (Figure 2.4). The tank farm contains four above ground storage tanks holding approximately 3 million gallons of jet fuel, which are surrounded by asphalt-covered secondary containment berms.

At the southeastern corner of PS-1 is a fuel truck loading station; this area will be designated as PS-1A for the purpose of identifying it as a separate bioventing site within PS-1. The loading station is used when the pipeline distribution system is not in service. The area near monitoring well MW-208 will be designated as an additional bioventing site, PS-1B, where soil, groundwater, and soil-gas contamination have also been detected. The area within the fence is a designated Class I, Group D Hazardous Location due to potential for flammable fuel vapors.

Table 2.1a
Soil Analytical Results
PS–2
Fairchild AFB, Washington

	Analyte:	Moisture	TRPH	Benzene	Toluene	Ethylbenzene	Total Xylenes
	Method:	NR	418.1	(note 1)			
Location	Depth (ft bgs)	% by wt.	concentrations in mg/kg				
MW–56	3.0–3.5	10					
	8.0–8.5	7					
	13–13.5	9					
MW–109	6.0–6.5	NA	460			1.0	3.2
	10.5–11.0	NA	170				
B–1	2.5–4.0	11.2			1.8	3.4	19.5
	5.0–5.5	17.1	887	2.4		2.1	11.5
B–2	3.4–4.0	13.8	1,278			2.7	16.5
	3.5–5.0	13.5	525			2.1	8.9
	5.0–6.0	13.8					
B–3	2.5–4.0	10	1,151			1.8	9.9
	4.0–5.5	12.5	475		2.2	7.5	41.2
B–4	2.5–4.0	13.2					
	8.5–10.0	20.5	126		2.1		14.1
B–5	4.0–5.5	20.6	168				
	8.5–10.0	16.4	628		9.4		92.1
B–8	5.0–6.5	21.9	466				
	8.0–9.5	12.5					
B–9	5.0–6.5	18	263				
	5.0–6.5	24	377				
	8.0–9.5	10.6					
PS2–BH1	3–3.5	10					
001	0–2	NA					
002	2–6	NA					0.007
	6–10	NA					0.014
003	0–2	NA					
	2–6	NA					
	2–6 (dup)	NA					
004	0.5–10 (comp)	NA					
007	0–6.5 (comp)	NA	1,200				
009	0–2	NA					
	4–6	NA					
010	2–6	NA					

LEGEND

ft bgs : feet below ground surface
NR : not reported
TRPH : Total recoverable petroleum hydrocarbons
(dup): duplicate sample
(comp): composite sample
note 1: soil borings B–1 through B–9 analyzed by EPA 5030/8020; all other samples analyzed by EPA 8240

[shaded] : not detected
NA : not analyzed

SOURCE : SAIC (1990), Halliburton NUS (1993)

tab21a
08/06/93

Table 2.1b
Groundwater Analytical Results at
PS-2
Fairchild AFB, Washington

Analyte:	TRPH	Benzene	Toluene	Ethylbenzene	Total Xylenes
Method:	418.1	8240			
Location	concentrations in $\mu g/L$				
MW-56					
MW-109	4,400	40		190	420
MW-109 (dup)	4,000	40		170	240
MW-177	27,000	240		520	2,200

LEGEND

NOTE: Results reported from Round 11 (January 1992)

TRPH : Total recoverable petroleum hydrocarbons

(shaded) : not detected

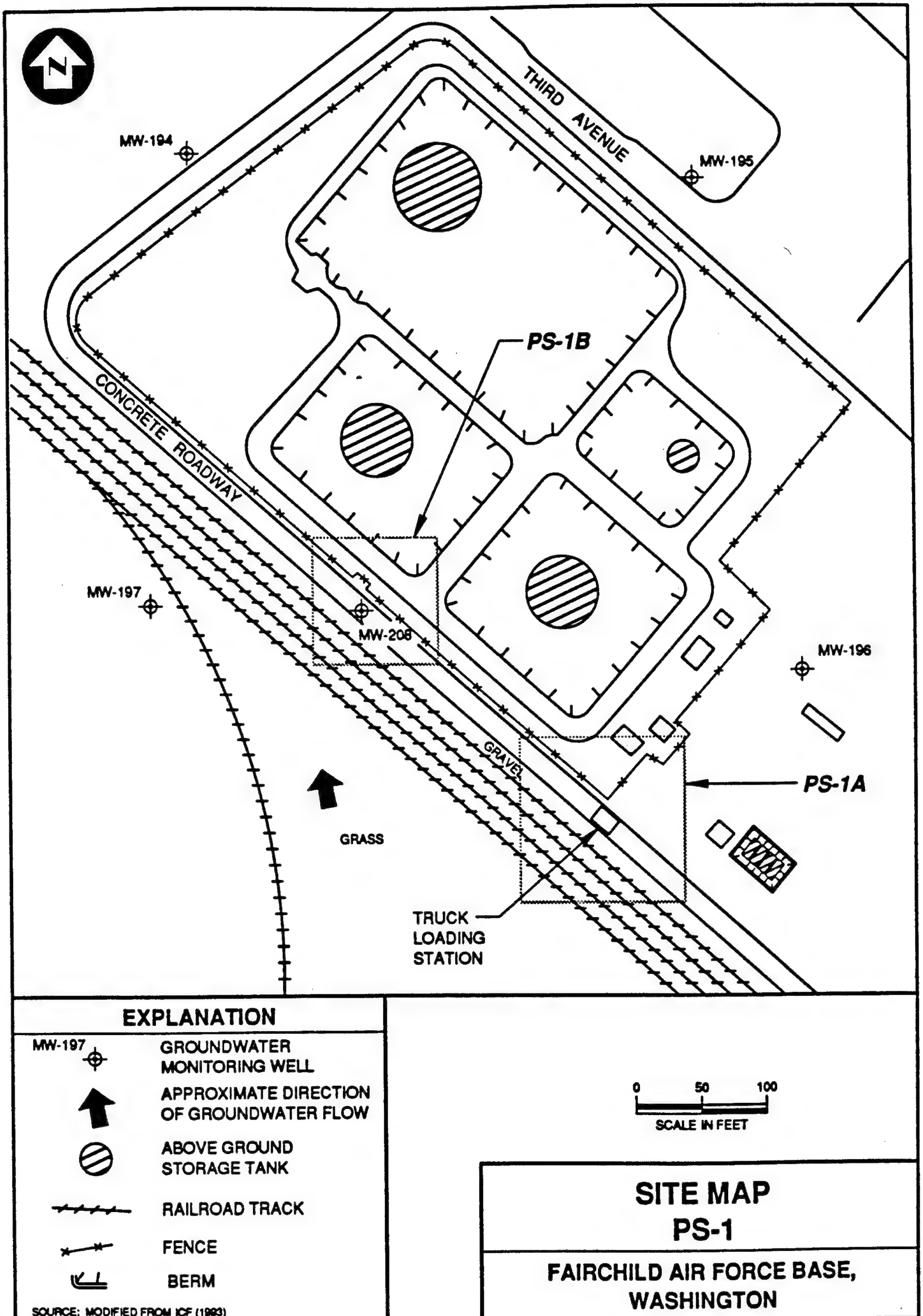
(dup) : duplicate sample

tab21b

SOURCE : SAIC (1990), Halliburton NUS (1993)

08/06/93

FIGURE 2.4



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2.2.2 Site History

The tank farm was initially constructed in 1951 with one storage tank and then expanded to three tanks in 1956 and four tanks in 1960. Only jet fuels have been stored at the site. Historically, fuel was received via railroad tank cars, although fuel is now received via underground pipeline from a distant refinery. Fuel spills are known to have occurred during fuel transfer operations. In 1990, 4,500 gallons of jet fuel were released within the bermed area and 3,000 gallons were estimated to have been recovered. Bottom sludges from the tanks were also weathered within the bermed areas. During installation of a fuel containment system at the truck loading area in 1990, visibly contaminated soils were discovered by Fairchild AFB personnel.

2.2.3 PS-1A Site Geology

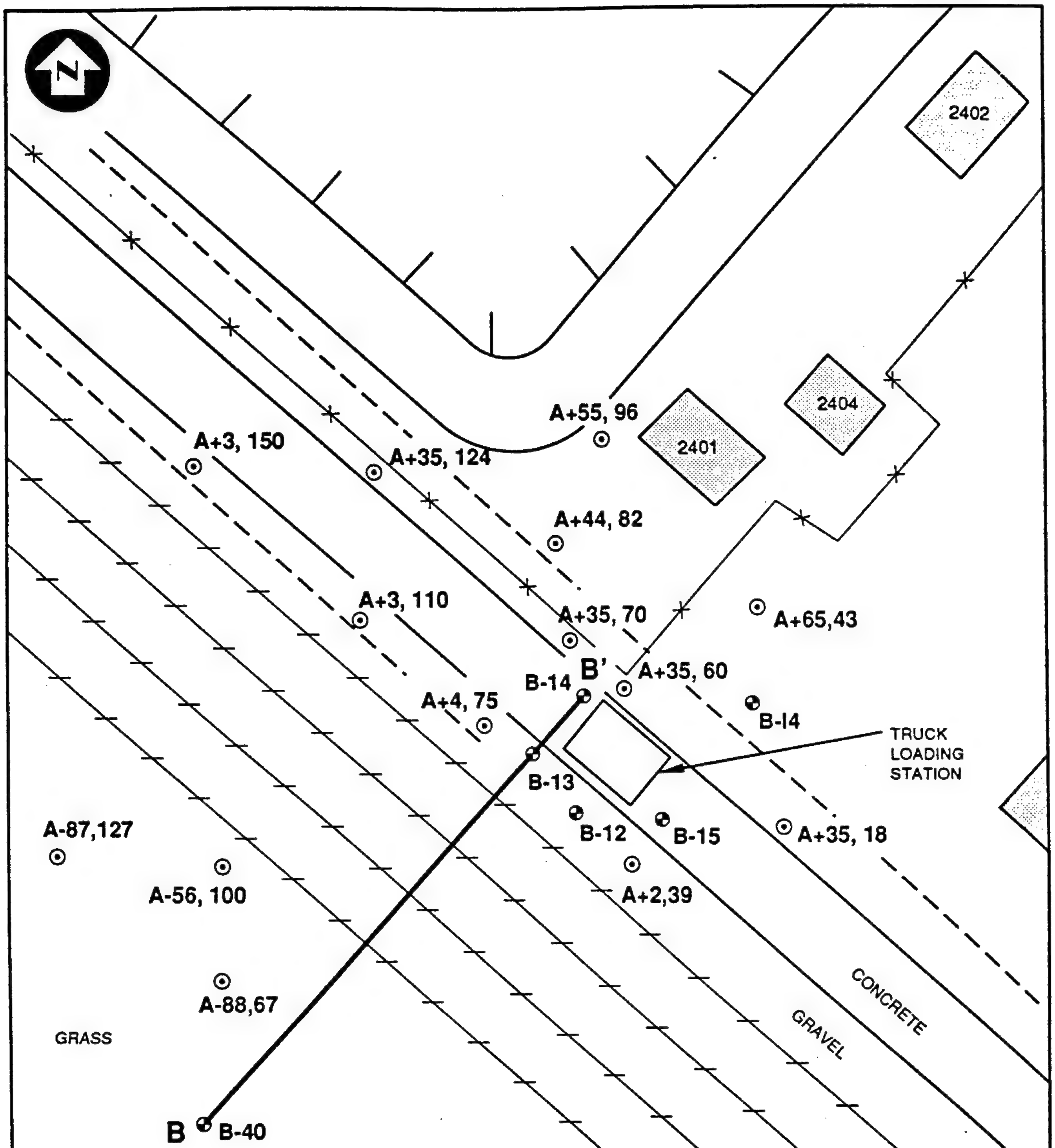
Figure 2.5 shows the location of 6 soil borings and 14 soil-gas survey points located in the area as part of recent PS-1 site investigations (ICF 1993a, ICF 1993b). Figure 2.6 shows geologic cross-section B-B', constructed from three of the soil boring logs, which generally follows a southwest to northeast direction though the PS-1A site. A laterally continuous sandy silt layer occurs from ground surface to a depth of 3 to 5 feet bgs, with the exception of the northern part of the cross-section where railroad ballast material and concrete is found at the surface. Underlying the sandy silt is a sand interval approximately 5 to 7 feet in thickness. Beneath the silty sand is a stiff clay layer with minor sand fractions observed to the termination of the borings at 12 feet bgs. Other borings drilled at PS-1 indicate depth to the basalt bedrock ranges from 17 to 30 feet bgs, although weathered basalt has been found as shallow as 7 feet bgs. Jet fuel odor was noted during the drilling of soil borings B-12, B-13, and B-15.

Soils were described as saturated near the base of the silty sand interval at 8 to 10 feet bgs, possibly as a result of seasonally perched water on top of the underlying stiff clay. However, no groundwater was encountered in any of the five borings, all terminated at 10 to 12 feet bgs. Static water levels in monitoring wells at PS-1 are highly variable, depending on season and screened depths of the wells. No monitoring wells exist at the PS-1A area. The static level measured after drilling of MW-208, screened from 7 to 17 feet bgs in the silty sand and the underlying stiff clay interval, was approximately 4.5 feet bgs, while that measured for MW-197, screened from approximately 13 to 24 feet bgs in the stiff clay, a thin underlying sand interval, and the weathered basalt, was 15 feet bgs. Seasonal variations in groundwater levels of 2 to 3 feet have been measured.

The groundwater flow direction also appears to be variable, depending upon yearly snowmelt runoff. The direction was generally toward the north, based on groundwater levels taken in November 1991 and February 1992 (ICF 1993a). The hydraulic gradient was measured at approximately 0.007 ft/ft, based on water levels taken during the same time period. Recent investigations indicated a northeast groundwater flow direction attributed to heavy snowmelt runoff during the spring of 1993 (ICF 1993b).

2.2.4 PS-1A Site Contaminants

Petroleum hydrocarbons, volatile organics, and semivolatile organics have been detected in soil and soil gas at the PS-1A site. During drilling of the soil borings shown



EXPLANATION

B-40	SOIL BORING
A+65,43	SOIL GAS SAMPLE LOCATION
B B'	LINE OF GEOLOGIC CROSS-SECTION
	FUEL LINES
	FENCE
	RAILROAD TRACKS

SOURCE: MODIFIED FROM ICF (1993b)

SAMPLE LOCATIONS PS-1A

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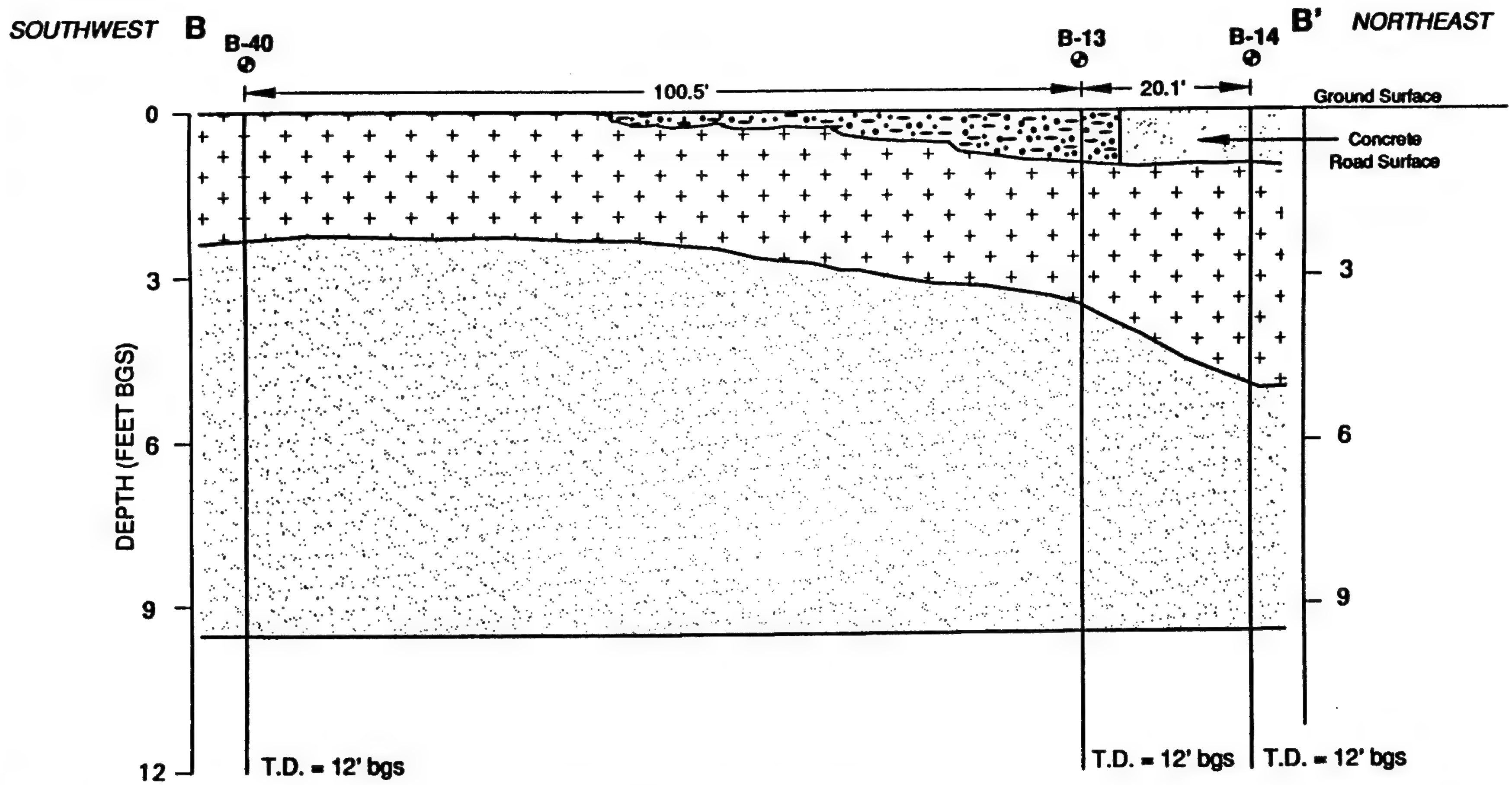

NOTE: BOREHOLES WERE CONTINUOUSLY LOGGED.

EXPLANATION

B-40 SOIL BORING

GEOLOGIC CONTACT

SOURCE: MODIFIED FROM ICF (1993b)

LITHOLOGIC DESCRIPTION

SILT - Brown to dark brown; minor to trace sand; firm; moist.

SAND - Gray-brown; moderate to well-graded; coarse to fine; subangular to subrounded; loose, moist

Clay - Red clay, stiff moist with minor sand and small gravel.

GRAVEL - Brown, poorly graded, small to medium, subangular to subrounded, minor sand, loose, wet.

SCALE IN FEET (HORIZONTAL EXAGGERATION IS 10.4X)

1
0
0 10 20

GEOLOGIC CROSS-SECTION B-B' PS-1A

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FIGURE 2.6

REV. 2 C260-14.DWG 08/19/93

in Figure 2.5, samples were collected and analyzed for volatile organics, semivolatile organics, and total petroleum hydrocarbons as diesel (TPH-d) (except at B-I4, where TRPH by EPA 418.1 was analyzed). Analytical results for borings B-12, B-13, B-14, B-15, and B-40 are shown in Table 2.2a. Results from boring B-I4, drilled prior to the other borings, are discussed below.

These results indicate maximum levels of contamination near B-12, B-13, and B-15, consistent with the petroleum odor noted on the soil boring logs. The maximum levels of contaminants found were 7,100 mg/kg TPH-d, 6.6 mg/kg toluene, 9.9 mg/kg ethylbenzene, and 103 mg/kg total xylenes, all found at B-15. Significant concentrations of other volatile organics and semivolatile organics were also found at B-12, B-13, and B-15, as shown in Table 2.2a. It is not known how deep residual fuel contamination exists in soils at the site, although none of the samples taken between 10 and 12 feet showed evidence of significant concentrations of fuel components.

No TRPH contamination was detected in soil boring B-I4. The maximum levels of other contaminants for this boring were: 0.1 mg/kg ethylbenzene (4-6 feet bgs), 11.87 mg/kg total xylenes (6-8 feet bgs), and 1.4 mg/kg bis(2-ethylhexyl)phthalate (0-2 feet bgs).

In March 1993, an extensive soil-gas survey was conducted throughout PS-1, including the PS-1A area near the truck loading station (ICF 1993b). Soil-gas survey points were shown in Figure 2.5 and soil-gas survey results are shown in Table 2.2b. These results indicate maximum levels of soil-gas contamination north and northwest of the truck loading area. The highest levels of the heavier aliphatics, which are more strongly sorbed to soils and less soluble in water, were found immediately north of the truck loading area. In addition to contaminated soils, the high levels of contaminated soil gas may be due to the northward flow of contaminated groundwater, or the migration of soil-gas or groundwater along underground utilities. The maximum levels of soil-gas contaminants found were: 3,570 ppmv total aliphatic hydrocarbons (A+44,82), 1.80 ppmv benzene (A+35,60), 25.6 ppmv toluene (A+35,18), 0.15 ppmv ethylbenzene (A+65,43), and 26.78 ppmv total xylenes (A+3,150).

No groundwater monitoring wells have been installed in the immediate vicinity of the truck loading station, so it is not known if groundwater has been impacted.

2.2.5 PS-1B Site Geology

Figure 2.7 shows the location of MW-208 and 10 soil-gas survey points located in the area as part of recent PS-1 site investigations (ICF 1993a, ICF 1993b). Figures 2.8a and 2.8b show the well log for monitoring well MW-208, which is located approximately 270 feet northwest of the truck loading area and the PS-1A site.

In the MW-208 borehole, sandy silt layer was found from ground surface to a depth of approximately 5 feet bgs, underlain by a sand layer about 6.5 feet in thickness. Beneath the sand is a stiff clay layer with a minor silt fraction observed to the termination of the boring at about 18 feet bgs. Soils were described as saturated and containing a JP-4 odor at 6 to 8 feet bgs. This soil profile encountered in MW-208 is similar to that found in soil borings at PS-1A. Jet fuel odor was noted in the sand zone at 5 to 8 feet bgs during

Table 2.2a
Soil Analytical Results for PS-1A
Fairchild AFB, Washington

		ASTM D2216	CA LUFT 8015	Volatile Organic Compounds (SW5030/8260)																	Semivolatile Organic Compounds (SW3050/8270)				
Location	Depth (ft bgs)	Moisture Content (%)	TPH-d	Benzene	Toluene	Ethylbenzene	Total Xylenes	Methylene chloride	Naphthalene	p-isopropyltoluene	1,4-dichlorobenzene	n-butylbenzene	SEC-butylbenzene	t-butylbenzene	Isopropylbenzene	Isopropyltoluene	n-propylbenzene	1,2,4-trimethylbenzene	1,3,5-trimethylbenzene	2,4,6-tribromophenol	2-fluorobiphenol	2-fluorophenol	2-methylnaphthalene	Naphthalene
			Concentrations reported in mg/kg																					
B-12	0 - 2	6.6	7					0.0080												NA	NA	NA	NA	NA
	2 - 4	17.9	610		0.92	4.6	16.7	0.59	2.5	2.3					0.66			6.3	1.3	NA	NA	NA	NA	NA
	2 - 4*	18.9	3,000				0.076											0.022	0.016	NA	NA	NA	NA	NA
	4 - 6	14.7	1,400				4.0	0.14		2.3								4.5	7.0	NA	NA	NA	NA	NA
	6 - 8	16.5																		NA	NA	NA	NA	NA
	8 - 10	14.7	470						0.007											5.14	1.64	4.25	2.40	1.30
	10 - 12	17.5																		NA	NA	NA	NA	NA
B-13	0 - 2	6.7	34								0.016									NA	NA	NA	NA	NA
	2 - 4	23.5																		NA	NA	NA	NA	NA
	4 - 6	13.7	100																	NA	NA	NA	NA	NA
	6 - 8	14.4	820				16		3.5	4.0		2.2		2.3				24	16	5.25	1.63	5.65	5.10	
	8 - 10	16.9	23																0.15	NA	NA	NA	NA	NA
	10 - 12	17.2																		NA	NA	NA	NA	NA
B-14	0 - 2	14.9																		NA	NA	NA	NA	NA
	2 - 4	19.4																		NA	NA	NA	NA	NA
	2 - 4*	19.8																		NA	NA	NA	NA	NA
	4 - 6	14.0																		NA	NA	NA	NA	NA
	6 - 8	18.1																		NA	NA	NA	NA	NA
	8 - 10	15.1									0.008									5.03	1.34	4.09		NA
	10 - 12	17.0			0.006															NA	NA	NA	NA	NA
B-15	0 - 2	15.8	1,300		6.6	2.4	103		3.0	10					1.5		2.0	74	54	NA	NA	NA	NA	NA
	2 - 4	22.7	7,100			0.70	12.7			2.7		2.1	0.74		0.51		0.95	21	12	5.70	1.01	5.55	4.90	3.50
	4 - 6	16.0	770			0.90	10.5		1.1				0.56		0.50	1.7	1.1	12	7.8	NA	NA	NA	NA	NA
	6 - 8	15.1	76			9.9	94		3.6			8.2	3.8	6.3	4.2	10	8.1	74	52	NA	NA	NA	NA	NA
	8 - 10	16.3	190						0.0073			0.011				0.041		0.070	0.11	NA	NA	NA	NA	NA
	10 - 12	18.5																		NA	NA	NA	NA	NA
B-40	0 - 2	21.9			0.021		0.022											0.007	0.006	NA	NA	NA	NA	NA
	2 - 4	10.1																		NA	NA	NA	NA	NA
	4 - 6	11.8																		NA	NA	NA	NA	NA
	6 - 8	20.2																		3.04	1.38	2.45		
	8 - 10	12.9																		NA	NA	NA	NA	NA
	10 - 12	19.2																		NA	NA	NA	NA	NA

NOTES:

ft bgs : feet below ground surface
TPH-d : total petroleum hydrocarbons as diesel
mg/kg : milligrams per kilogram (ppm)
* : duplicate sample
(blank box) : not detected
NA : not analyzed

tab22a
8/11/93

Table 2.2b
Soil Gas Analytical Results at PS−1A
Fairchild AFB, Washington

		Aliphatic Hydrocarbons						Volatile Organic Compounds				
		n−Hexane	n−Heptane	n−Octane	n−Nonane	n−Decane	Total	Benzene	Toluene	Ethyl− benzene	Total Xylenes	Total Unknowns
	Method:	GC/AID						GC/AID				
Location	Depth (ft bgs)	Concentrations reported in ppmv										
A+2,39	3											
A+3,110	3	95.80	151.0	77.80	9.15	1.65	335.40		5.95		2.40	
A+3,150	3	9.99	23.00	19.70	17.00	9.50	79.19	0.45			26.78	1.04
A+35,124	3	251.0	115.5	545.8			912.30					
A+35,18	3				0.172		0.172		25.60		21.70	
A+35,60	3	83.0	277.0	361.0		62.0	783.00	1.80				107.0
A+35,70	3	509.5	1,072	467	168.5		2,216.5					
A+4,75	3	4.09	20.93	23.34	6.07	8.17	62.60		2.19		7.39	7.09
A+44,82	3	1,730	1,620	220			3,570.0					
A+55,96	3				0.08		0.08					1.87
A+65,43	3	0.025	0.103				0.127	0.692		0.148	0.643	0.056
A−56,100	3	0.18		7.51	3.69	19.80	31.17					6.47
A−87,127	3				0.89		0.89					
A−88,67	3				0.097		0.097					

LEGEND

bgs : below ground surface

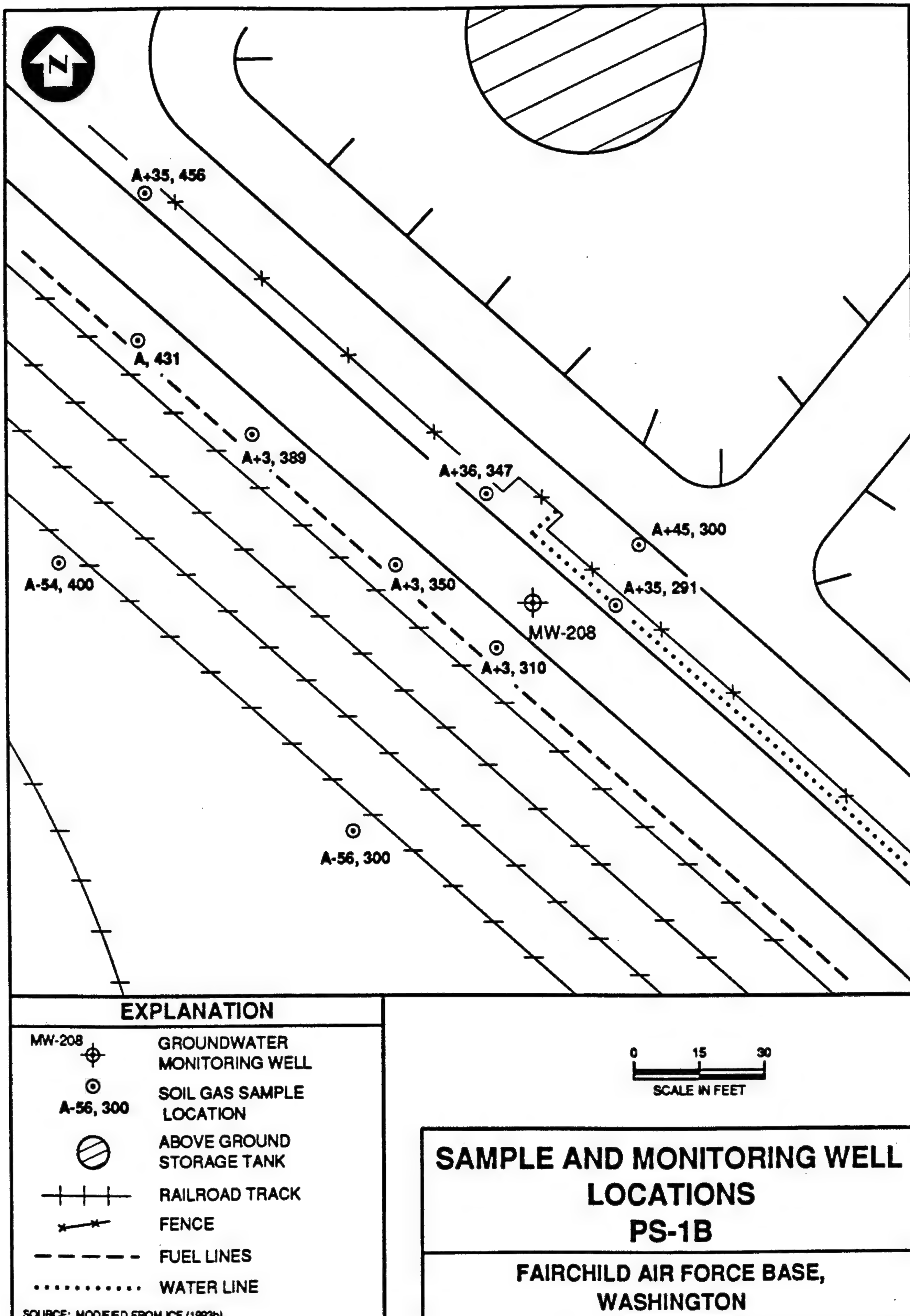
(shaded) : not detected

source: ICF (1993b)

tab22b

08/12/93

FIGURE 2.7



SAMPLE AND MONITORING WELL LOCATIONS
PS-1B

FAIRCHILD AIR FORCE BASE, WASHINGTON

REV. 2 C258-18.DWG 08/19/93

ENGINEERING-SCIENCE, INC.

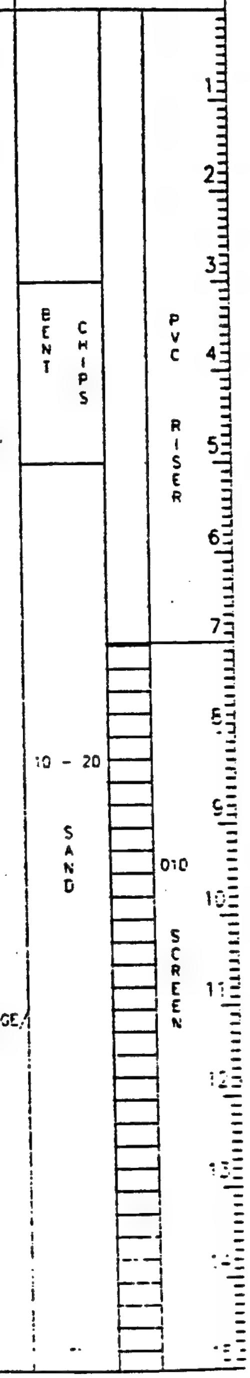
ES ENGINEERING-SCIENCE, INC.

WELL DRILLING LOG

PROJECT	FAFB 05392-303-02	WELL ID.	MW-208
DATE(S) DRILLED	5-05-93	RIG TYPE	SCHRAMM
GEOLOGIST/ENGINEER	D. NOE	LOCATION	PS-1
GEOLOGIST/ENGINEER		WATER LEVEL	N/A
DRILLING SUBCONTRACTOR	ENVIRONMENTAL WEST	TOTAL DEPTH OF HOLE	19 FEET

DEPTH (ft)	RECOVERY (%)	BLOWS/6in.	METER READING	SAMPLE ID.	SAMPLES	GENERAL LITHOLOGY	MATERIALS DESCRIPTION
		8					(SP) TOP 4": SILTY GRAVEL; ANGULAR TO SUBR BASALT GRAVEL; LOOSE, WET (PROBABLY DUE TO CONCRETE CORINGS); GRAY.
1	50%	20, 8	0				(OH) BOTTOM 1': SANDY SILT; COARSE TO FINE SUBR SAND; OCCASIONAL SMALL SUBR GRAVEL; FIRM, DARK BROWN (ORGANICS), MOIST.
2		18		FAFB-PS1-S48			SILT, MINOR SAND STA.;MINOR CLAY; FIRM, MOIST, DARK BROWN.
3	90%	17, 14	0				
4		14, 2		FAFB-PS1-S49			TOP 6": STA
5	80%	8, 17	50				(SW) BOTTOM 1'6": SAND,WELL GRADED; COARSE TO FINE, SUBA TO SUBR SAND; MINOR FINES; JP4 ODOR; LOOSE, WET, GRAY.
6		15, 12		FAFB-PS1-S50			STA.; JP4 ODOR; INCREASING WATER.
7	40%	15, 15	100				
8		25, 10					STA.; INCREASING COARSE FRACTION; SATURATION IN BOREHOLE, SLIGHT JP4 ODOR.
9	90%	29, 36	1				
10		40, 12					TOP 1': STA.
11	90%	17, 45	1				(CH) BOTTOM 1': CLAY, MINOR SILT; STIFF, MOIST, ORANGE/RED.
12		50, 25					CLAY; STA.; HEAVING SANDS AT TOP OF SAMPLE.
13	20%	50+	0				
14		15					CLAY, STA., NO HEAVING SANDS.
15	15%	47					

WELL DIAGRAM



SOURCE: ICF (1993)

ES ENGINEERING-SCIENCE, INC.

WELL DRILLING LOG

PROJECT	FAFB 05392-303-02	WELL ID.	MW-208	PAGE 2
DATE(S) DRILLED	5-05-93	RIG TYPE	SCHRAMM	
GEOLOGIST/ENGINEER	D. NOE	LOCATION	PS-1	
GEOLOGIST/ENGINEER		WATER LEVEL	N/A	
DRILLING SUBCONTRACTOR	ENVIRONMENTAL WEST	TOTAL DEPTH OF HOLE	19 FEET	

DEPTH (ft)	RECOVERY (%)	BLOWS/6in.	METER READING	SAMPLE ID.	SAMPLES	GENERAL LITHOLOGY	MATERIALS DESCRIPTION	WELL DIAGRAM
		50+					(CH) CLAY	10 - 20 SAND; SCREEN
16								16
17								17
		12					(CH) CLAY; STA	
	15%	30	0					
18								18
		50+						
19								19
20								20
21								21
22								22
23								23
24								24
25								25
26								26
27								27
28								28
29								29
30								30

SOURCE: ICF (1993)

drilling of MW-208. Other borings drilled at PS-1 indicate basalt and weathered basalt occurs at Table 2.3a approximately 17 to 30 feet bgs.

The static water level measured after drilling of MW-208, screened from 7 to 17 feet, was approximately 4.5 feet bgs. Groundwater flow at PS-1B is assumed similar to that discussed for PS-1A in Section 2.2.3.

2.2.6 PS-1B Site Contaminants

Petroleum hydrocarbons and volatile organics have been detected in soil, soil gas, and groundwater at the PS-1B site. During drilling of monitoring well MW-208 at PS-1B in March 1992, soil samples were collected and analyzed for volatile organics and total petroleum hydrocarbons as diesel (TPH-d). The analytical results are shown in Table 2.3a.

These results indicate significant levels of soil contamination at MW-208, consistent with the description of JP-4 odor noted on the soil boring log. The maximum levels of contaminants found at MW-208 were: 900 mg/kg TPH-d, 19.5 mg/kg total xylenes, 44 mg/kg trimethylbenzenes, 1.6 mg/kg p-isopropyltoluene. and 3.2 mg/kg n-propylbenzene. It is not known how deep residual fuel contamination exists in soils at the site since the deepest samples (6 to 8 feet bgs) had significant concentrations of fuel components; however, JP-4 odor was not noted below 8 feet bgs during drilling.

In March 1993, an extensive soil-gas survey was conducted throughout PS-1, including the PS-1B area near MW-208 (ICF 1993b). Soil-gas survey points were shown in Figure 2.7 and soil-gas survey results are shown in Table 2.3b. These results indicate highest levels of soil-gas contamination were found near MW-208 and along the fuel line west of MW-208. The maximum levels of contaminants found in *in situ* soil gas were: 1,700 ppmv total aliphatic hydrocarbons (A+3,350), 8.75 ppmv benzene (A+3,389), 22.84 ppmv toluene (A,431), 1.95 ppmv ethylbenzene (A+3,310), and 30.05 ppmv total xylenes (A+3,310). Soil gas from the headspace of a water sample collected at A+36,347 also indicated significant contamination.

Contamination of groundwater has been documented in monitoring well MW-208. Groundwater analytical results from May 1993 for TPH-d, volatile organics, and semi-volatile organics are shown in Table 2.3c.

2.3 Building 2034

2.3.1 Site Location and Description

Building 2034 is the JP-4 fuels lab located approximately 70 feet west of Building 2035 and the underground fuel storage area (Figure 2.9). This underground fuel storage area is located north of the flightline (northeast of Taxiway No. 3) and north of hangar Building 1009. Building 2034 is set on a concrete foundation with no basement. The area around Buildings 2034 and 2035 is gravel covered and surrounded by a fence. The area within the fence is a designated Class I, Group D Hazardous Location due to potential for flammable fuel vapors.

Table 2.3a
Soil Analytical Results for PS-1B
Fairchild AFB, Washington

	Method:	ASTM DD2216	CA LUFT 8015	SW5030/8260 (Volatile Organic Compounds)								
Location	Depth (ft bgs)	Moisture Content	TPH-d	Benzene	Toluene	Ethylbenzene	Total Xylenes	Methylene Chloride	1,2,4-trimethylbenzene	1,3,5-trimethylbenzene	p-isopropyltoluene	n-propylbenzene
		% by wt.	Concentrations reported in mg/kg									
MW-208	2 - 4	22.6					0.005	0.137		0.02		
	4 - 6	18	63					0.095				
	6 - 8	14.8	900				19.50		25	19	1.6	3.2

LEGEND

TPH-d : Total Petroleum Hydrocarbons as diesel

bgs : below ground surface

(shaded) : not detected

source: ICF (1993b)

tab23a

8/11/93

Table 2.3b
Soil Gas Analytical Results at PS−1B
Fairchild AFB, Washington

		Aliphatic Hydrocarbons						Volatile Organic Compounds				
		n−Hexane	n−Heptane	n−Octane	n−Nonane	n−Decane	Total	Benzene	Toluene	Ethyl−benzene	Total Xylenes	Total Unknowns
	Method:	GC/AID						GC/AID				
Location	Depth (ft bgs)	Concentrations reported in ppmv										
A,431	3	24.71	45.73	22.14		17.68	110.26	1.23	22.84		0.789	
A+3,310	3	17.55	139.7	276.3	101.2	116.50	651.2		7.90	1.95	30.05	51.45
A+3,350	3	193.5	842.0	392.5	272.0		1,700.0					
A+3,389	3	172.55	457.0	306.5		40.05	976.1	8.75	19.60		20.70	
A+35,291[1]	3	0.26	0.36	0.39			1.01				9.45	26.0
A+35,456[1]	3		0.780	0.400			1.18				55.73	179.0
A+36,347[2]	3	478.4	4,438	6,128			11,044				875.2	47,840
A+45,300[2]	3											
A−54,400	3	0.7943					0.7943					
A−56,300	3	14.84					14.84					

LEGEND

bgs : below ground surface

(shaded cell) : not detected

1 : soil gas result from water sample headspace

2 : soil gas result from soil sample headspace

source: ICF (1993b)

tab23b

06/12/93

Table 2.3c
Groundwater Analytical Results for PS-1B
Fairchild AFB, Washington

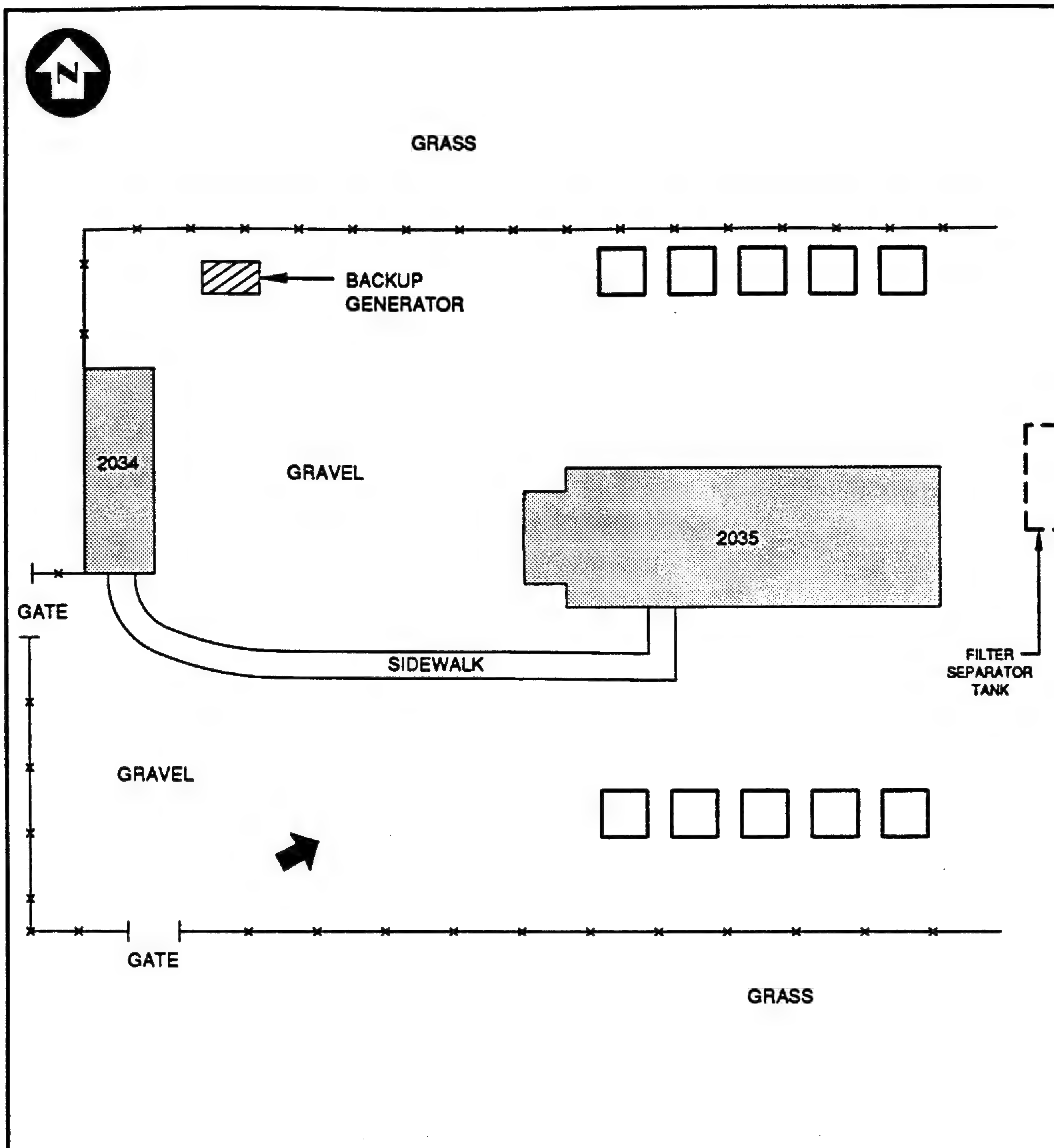
	CA LUFT 8015	Volatile Organic Compounds									Semivolatile Organic Compounds			
Method:	CA LUFT 8015	SW5030/8260									SW3050/8270			
Location	TPH-d	Benzene	Toluene	Ethylbenzene	Total Xylenes	Isopropylbenzene	Naphthalene	1,2,4-trimethylbenzene	1,3,5-trimethylbenzene	n-propylbenzene	2-methylnaphthalene	Naphthalene	2,4,6-tribromophenol	2-fluorobiphenol
	Concentrations reported in μgL													
MW-208	7.0	660		670	3,050	52	89	540	430	65	51	110	9.4	105

LEGEND
TPH-d : Total Petroleum Hydrocarbons as diesel
bgs : below ground surface
(shaded) : not detected
source: ICF (1993b)

tab23c

8/11/93

FIGURE 2.9



EXPLANATION

FENCE

VAULT

APPROXIMATE DIRECTION
OF GROUNDWATER FLOW
(SURFICIAL AQUIFER)

SOURCE: FAIRCHILD AFB (1993)
HALLIBURTON NUS (1993)

0 15 30
SCALE IN FEET

BUILDING 2034 AND BUILDING 2035 SITE MAP

FAIRCHILD AIR FORCE BASE, WASHINGTON

REV. 2 C258-19.DWG 08/20/93

ENGINEERING-SCIENCE, INC.

2.3.2 Site History

In March 1990, an underground waste fuel tank immediately east to Building 2034 (fuels lab) was removed (Figure 2.10). The tank was approximately 250 gallons in size and was used to store waste JP-4 fuel poured down the sink from the fuels lab. The excavation to remove the tank was approximately 9 feet by 9 feet square and 10 feet deep and was backfilled with clean, sandy fill. Approximately 24 yd3 of soil were removed from the excavation; however, soils at the bottom and sides of the excavation were still visibly contaminated and smelled of fuel.

2.3.3 Site Geology

The geology of the site is expected to be similar to that for Building 2035 given their close proximity. The geology for Building 2035, where some exploratory soil borings have been drilled, is discussed in Section 2.4.3. Groundwater was not encountered at Building 2034 during excavation to 10 feet bgs.

2.3.4 Site Contaminants

During tank removal operations, one soil sample was collected from the bottom of the excavation (Figure 2.10). The sample was analyzed for TRPH (EPA 418.1) and a level of 1,900 mg/kg TRPH was detected.

It is not known if groundwater has been impacted at the site.

2.4 Building 2035

2.4.1 Site Location and Description

Building 2035 is the pump house for the fuel storage area, located north of the flightline (northeast of Taxiway No. 3) and north of hangar Building 1009 (shown on Figure 2.9). The area contains 10 underground fuel storage tanks extending to a depth of approximately 15 feet, each capable of storing approximately 50,000 gallons of JP-4 fuel. One underground 2,000-gallon filter-separator tank is located east of the tanks. The area around Buildings 2034 and 2035 is gravel covered and surrounded by a fence. The area within the fence is a designated Class I, Group D Hazardous Location due to potential for flammable fuel vapors.

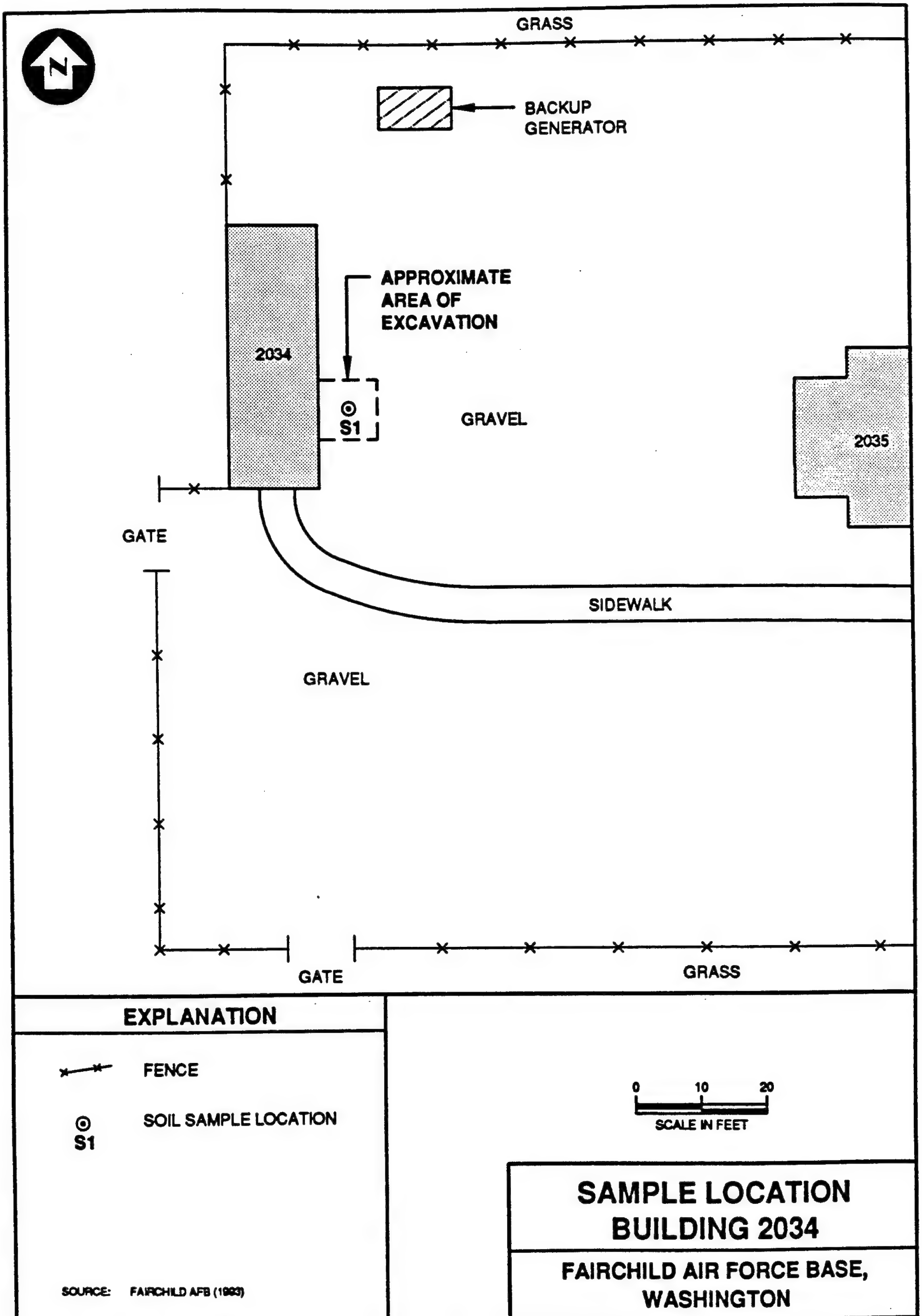
2.4.2 Site History

The 10 fuel tanks have been in operation for approximately 40 years. The tanks are made of steel and currently have cathodic protection and automatic valves to prevent overfill. However, the area is heavily used and during a base-wide underground tank study conducted in December 1987, contaminated soils were discovered (RZA 1988).

2.4.3 Site Geology

Figure 2.11 shows the location of 12 soil borings drilled as part of the underground tank survey and 49 soil-gas survey points used for leak detection (Tracer Research Corp. 1989). Figure 2.12 shows geologic cross-section C-C', constructed from four of the soil boring logs, which follows a north to south direction through the site to a depth of approximately 15 feet bgs. A medium to coarse, sandy fill occurs from ground surface to

FIGURE 2.10



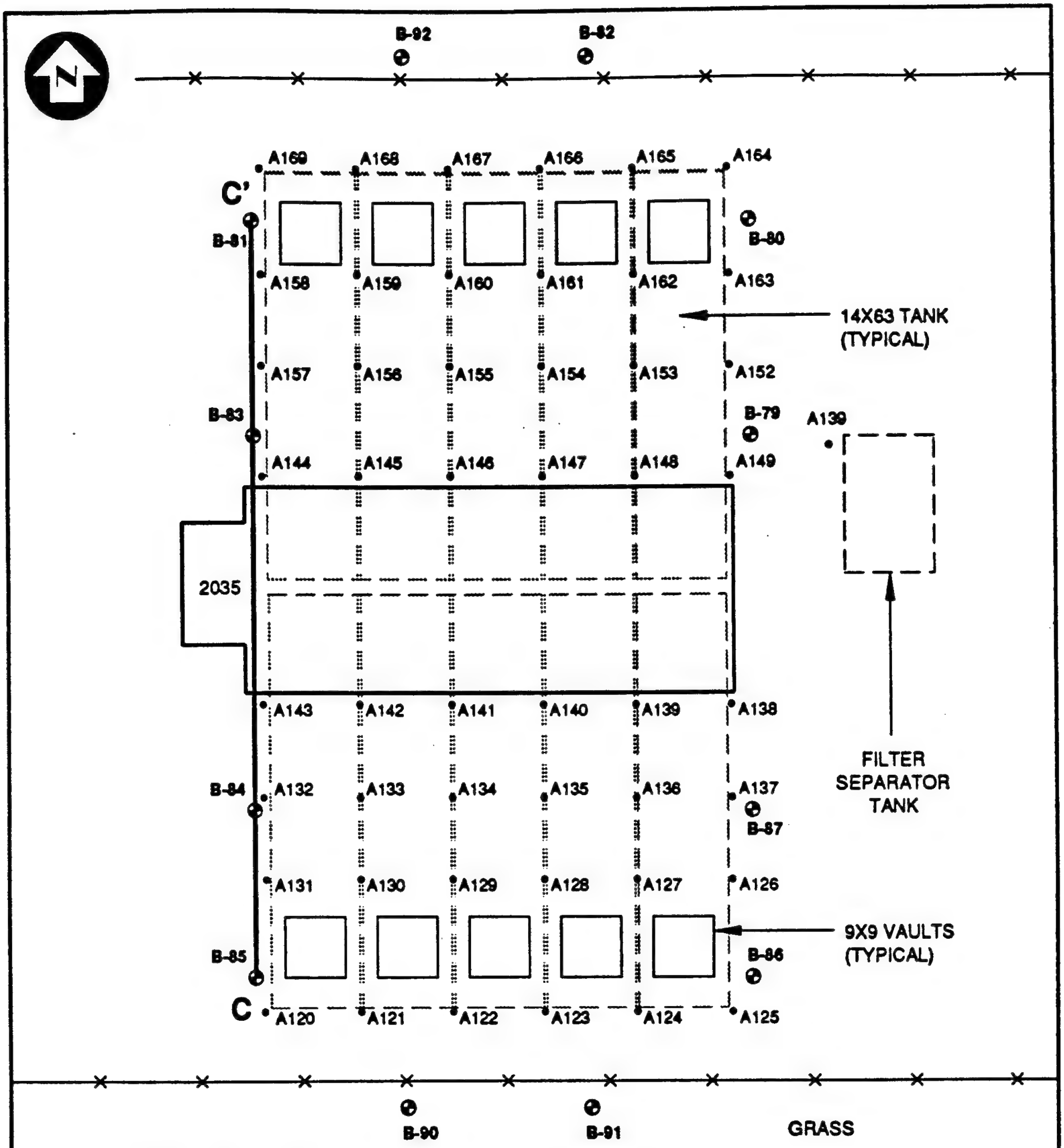
SAMPLE LOCATION BUILDING 2034

FAIRCHILD AIR FORCE BASE, WASHINGTON

REV. 1 C258-20.DWG 08/09/93

ENGINEERING-SCIENCE, INC.

FIGURE 2.11



EXPLANATION

	FENCE
B-13	SOIL BORING
	LINE OF GEOLOGIC CROSS-SECTION
•A120	SOIL GAS SAMPLE LOCATION
	UNDERGROUND FUEL STORAGE TANK

SOURCE: MODIFIED FROM RZA (1988)

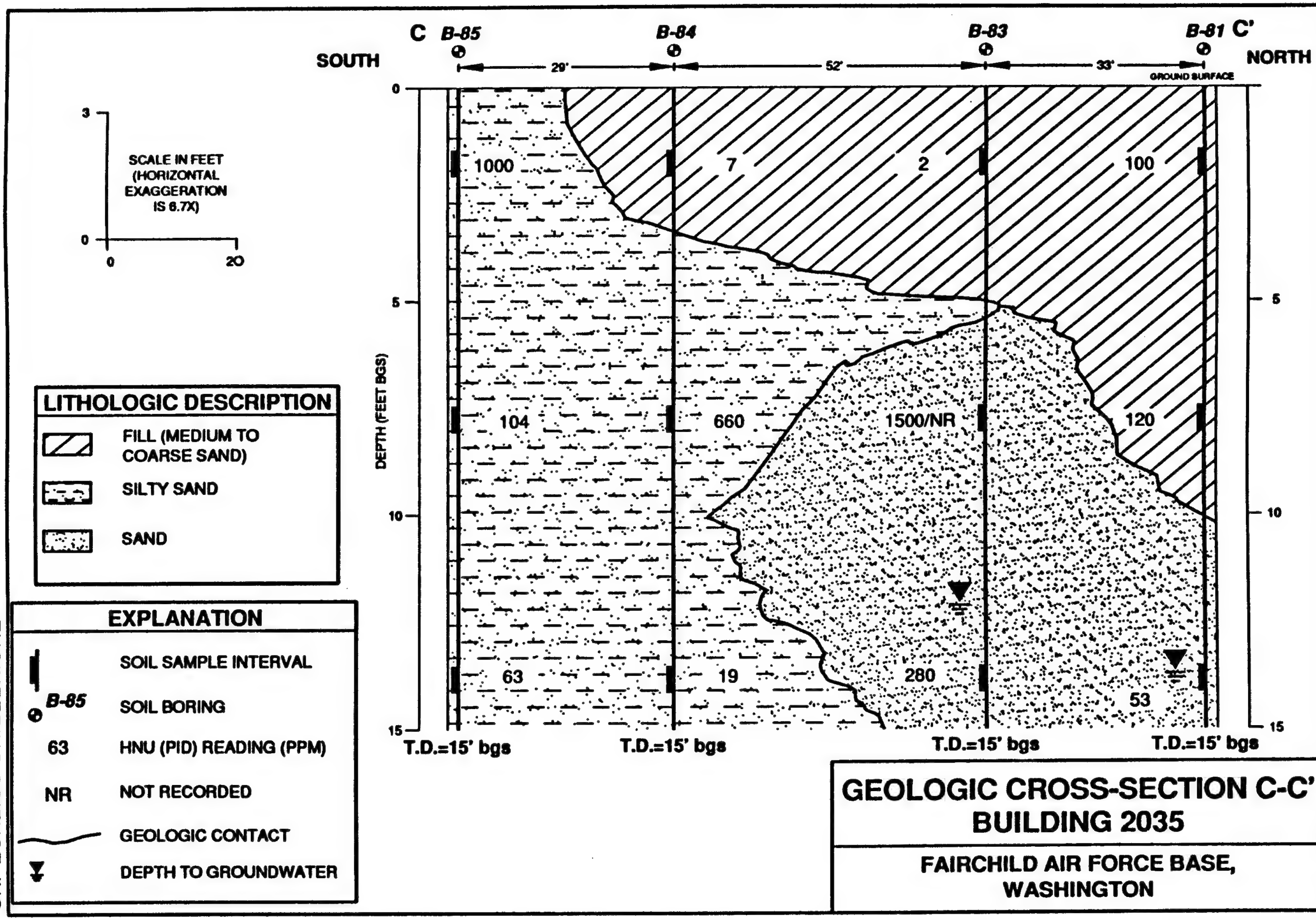
0 12.5 25
SCALE IN FEET

SAMPLE LOCATIONS BUILDING 2035

FAIRCHILD AIR FORCE BASE, WASHINGTON

REV. 2 C258-21.DWG 08/20/93

ENGINEERING-SCIENCE, INC.



GEOLOGIC CROSS-SECTION C-C'
BUILDING 2035

FAIRCHILD AIR FORCE BASE, WASHINGTON

FIGURE 2.12

between 5 and 10 feet bgs. This fill was also found in borings B-82, B-90, B-91, and B-92, which are 19 feet north and south of the tanks. Below the fill is native soil, described as a sand or silty sand in most borings, which continues to 15 feet bgs, where the borings were terminated. However, the native soil was described as a clayey silt/silty clay at 13.5 to 15.0 feet bgs in borings B-91 and B-92.

Jet fuel odor and sheen were noted in all borings drilled. Field instrumentation, an HNU photoionization detector (PID) and combustible gas indicator (CGI), were also used during drilling; results are shown in Table 2.4a.

Groundwater was encountered at 13.5 feet bgs and 12 feet bgs in borings B-81 and B-83, respectively. The groundwater flow direction appears to be north-northeast, based on water levels taken at monitoring wells south of the site in April 1992 (Halliburton NUS 1993).

2.4.4 Site Contaminants

No soil samples were collected during the underground tank survey, so no analytical results are available for the contaminated soils. However, based on PID and CGI readings collected during drilling, contaminated soil appears to be on all sides of the tanks (Table 2.4a). PID readings greater than 900 ppmv were recorded in borings B-82, B-83, B-85, B-87, and B-91 and CGI readings of 100% were recorded in borings B-82, B-84, B-85, B-86, and B-91. The highest PID readings for each borehole, except B-81, were recorded at the 7.5 to 9.0 ft. bgs interval.

Table 2.4b presents the results of a soil-gas survey conducted in October 1989; soil gas locations were shown in Figure 2.11. The highest levels of TVH (Total Volatile Hydrocarbons) found were: 590 ppmv (A122) 431 ppmv (A159 and A134), 399 ppmv TVH (A158), and 351 ppm TVH (A168). Three of these points are in the northwest area of the tanks. Readings above 100 ppmv were found in sample locations in the northwest and southern portions of the grid.

Table 2.4a
Soil Headspace Results for Building 2035
Fairchild AFB, Washington

Location	Depth (ft bgs)	PID (ppmv)	CGI[1] (%)
B-79	2.5-4.0	620	
	7.5-9.0	920	
	13.5-15.0	5	2
B-80	2.5-4.0	5	
	7.5-9.0	99	
	13.5-15.0	4	NR
B-81	2.5-4.0	100	
	7.5-9.0	120	
	13.5-15.0	53	NR
B-82	2.5-4.0	0	
	7.5-9.0	900	
	13.5-15.0	16	100
B-83	2.5-4.0	2	
	7.5-9.0	1,500	
	13.5-15.0	280	60
B-84	2.5-4.0	7	
	7.5-9.0	660	
	13.5-15.0	19	100
B-85	2.5-4.0	1,000	
	7.5-9.0	104	
	13.5-15.0	63	100
B-86	2.5-4.0	0	
	7.5-9.0	800	
	13.5-15.0	4	100
B-87	2.5-4.0	4	
	7.5-9.0	1,400	
	13.5-15.0	20	0
B-90	2.5-4.0	7	
	7.5-9.0	660	
	13.5-15.0	88	5
B-91	2.5-4.0	360	
	7.5-9.0	980	
	13.5-15.0	53	100
B-92	2.5-4.0	2	
	7.5-9.0	780	
	13.5-15.0	11	35

LEGEND

bgs : below ground surface
PID : photoionization detector
CGI : combustible gas indicator
NR : not reported
[1] : CGI readings taken within hollow-stem auger before removal from borehole.

source: RZA (1988)

tab24a

08/12/93

Table 2.4b
Soil Gas Results for Building 2035
Fairchild AFB, Washington

Location	Total Hydrocarbons (ppmv)
A120	2.87
A121	0.478
A122	590
A123	3.51
A124	123
A125	13.3
A126	28.7
A127	5.90
A128	0.319
A129	191
A130	35.1
A131	175
A132	0.112
A133	175
A134	431
A135	104
A136	63.8
A137	2.42
A138	43.1
A139	5.90
A140	55.8
A141	19.1
A142	25.5
A143	<0.002
A144	1.47
A145	223
A156	137
A157	0.638
A158	399
A159	431
A168	351
A169	1.59

tab24b

source: Tracer Research (1989)

08/11/93

3.0 SITE-SPECIFIC ACTIVITIES

The purpose of this section is to describe the work that will be performed by Engineering-Science, Inc. (ES) at each of the five sites. Activities that will be performed at each site include siting and construction of a central vent well (VW) and vapor monitoring points (VMPs), an initial pilot test (including an air permeability test and an in situ respiration test), and an extended (one-year) pilot test. Soil and soil-gas sampling procedures and the blower configuration that will be used to introduce air (oxygen) into contaminated soils by injection are also discussed in this section.

No dewatering or groundwater treatment will take place during the pilot testing. Pilot test activities will be confined to unsaturated soils remediation. Existing monitoring wells will not be used as primary air injection wells; however, monitoring wells which are known to have a portion of their screened interval above the water table may be used as VMPs or used to measure the composition of background soil gas.

Subsurface soils at all sites are expected to be composed of mostly interbedded sands, silts, and silty sands which should be very suitable for the bioventing technology.

During previous site investigations, soil moisture results from PS-2, PS-1A, and PS-1B indicated moisture contents from generally 10 to 20 percent (by wt.) at 5 to 10 feet bgs (Table 2.1a, Table 2.2a, and Table 2.3a), the expected screened interval for most sites. At PS-2, soil nutrient levels were measured for the composite soil samples taken at soil borings 004 and 007. Nutrient levels for soil boring 004 were: 490 mg/kg Total Kjeldahl Nitrogen (TKN), 45 mg/kg ammonia nitrogen, and 370 mg/kg total phosphorus. Nutrient levels for soil boring 007 were: 300 mg/kg TKN, 13 mg/kg ammonia nitrogen, and 460 mg/kg total phosphorus. These ranges of soil moisture and nutrient levels are expected to exist at all five bioventing sites and should be adequate to sustain respiration and biodegradation for the duration of the pilot tests.

3.1 Locations of Vent Wells and Vapor Monitoring Points

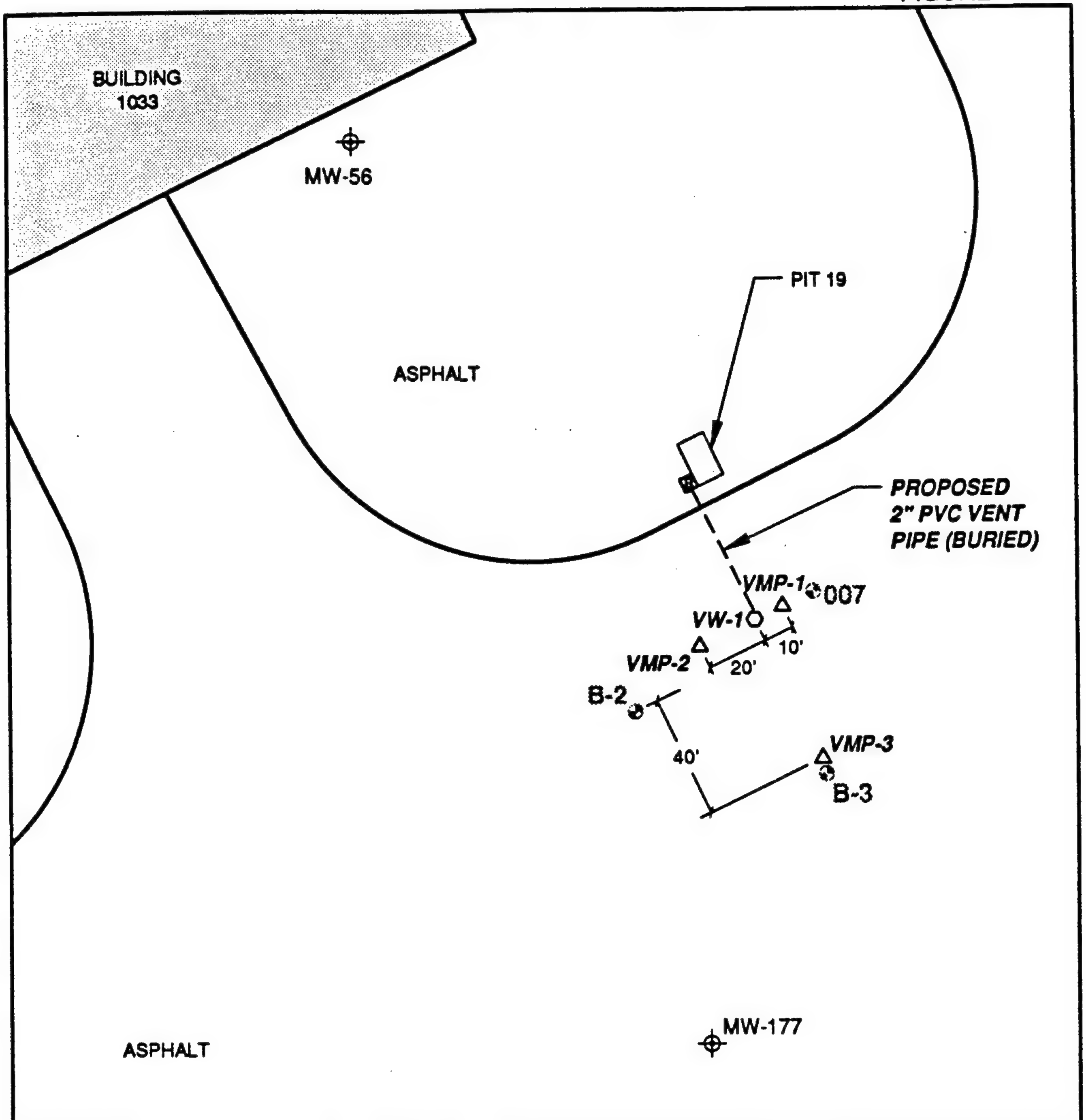
A general description of criteria used for siting a central VW and VMPs is included in the protocol document. The proposed VW and VMP locations and the siting criteria used for each site are described below. The proposed locations for the two background VMPs are described in Section 3.1.6.

The final location of VWs and VMPs may vary slightly from the proposed location if evidence of significant fuel contamination is not observed in borings. VWs will be located in areas of high fuel contamination which also is expected to be oxygen depleted (less than 5 percent). Increased biological activity should be stimulated by oxygen-rich soil gas ventilation during both the initial and extended pilot tests.

3.1.1 PS-2

Figure 3.1 shows the proposed location of the blower, the central VW, and the VMPs for PS-2. The VW location was chosen based upon the high degree of contamination at soil borings 007, B-2, and B-3 (see Table 2.1a).

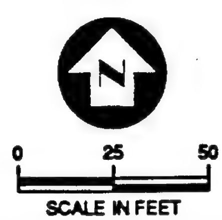
FIGURE 3.1



EXPLANATION

MW-177	GROUNDWATER MONITORING WELL
B-1	SOIL BORING
	PROPOSED BLOWER LOCATION
VW-1	PROPOSED VENT WELL
VMP-1	PROPOSED VAPOR MONITORING POINT

SOURCE: MODIFIED FROM HALLIBURTON NUS (1993)



PROPOSED VENT WELL AND VAPOR MONITORING POINT LOCATIONS PS-2

FAIRCHILD AIR FORCE BASE, WASHINGTON

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The radius of venting influence around the central VW is expected to be about 30 to 40 feet based upon the predominance of sands and silts in subsurface soils at the site and upon the expected shallow groundwater depth at 8 to 9 feet bgs. The three VMPs are to be located at distances from the central VW which should provide adequate coverage over this expected radius of influence. They are also located near soil borings where the highest levels of contamination have been documented.

3.1.2 PS-1A

Figure 3.2 shows the proposed location of the blower, the central VW, and the VMPs for PS-1A. The VW location was chosen based upon the high degree of contamination observed in borings immediately surrounding the truck loading station, the high levels of contamination found in soil gas north of the truck loading station (see Table 2.2a and Table 2.2b), and the need to avoid subsurface utilities.

The radius of venting influence around the central VW is expected to be about 30 to 40 feet based upon the predominance of sands in subsurface soils at the site and upon the expected shallow depth of groundwater. The three VMPs are to be located at distances from the central VW which should provide adequate coverage over this expected radius of influence. VMP-1 and VMP-2 are located near borings where the highest levels of contamination have been documented and VMP-3 is located in the area within the fenced area where the highest levels of soil gas contamination were found.

3.1.3 PS-1B

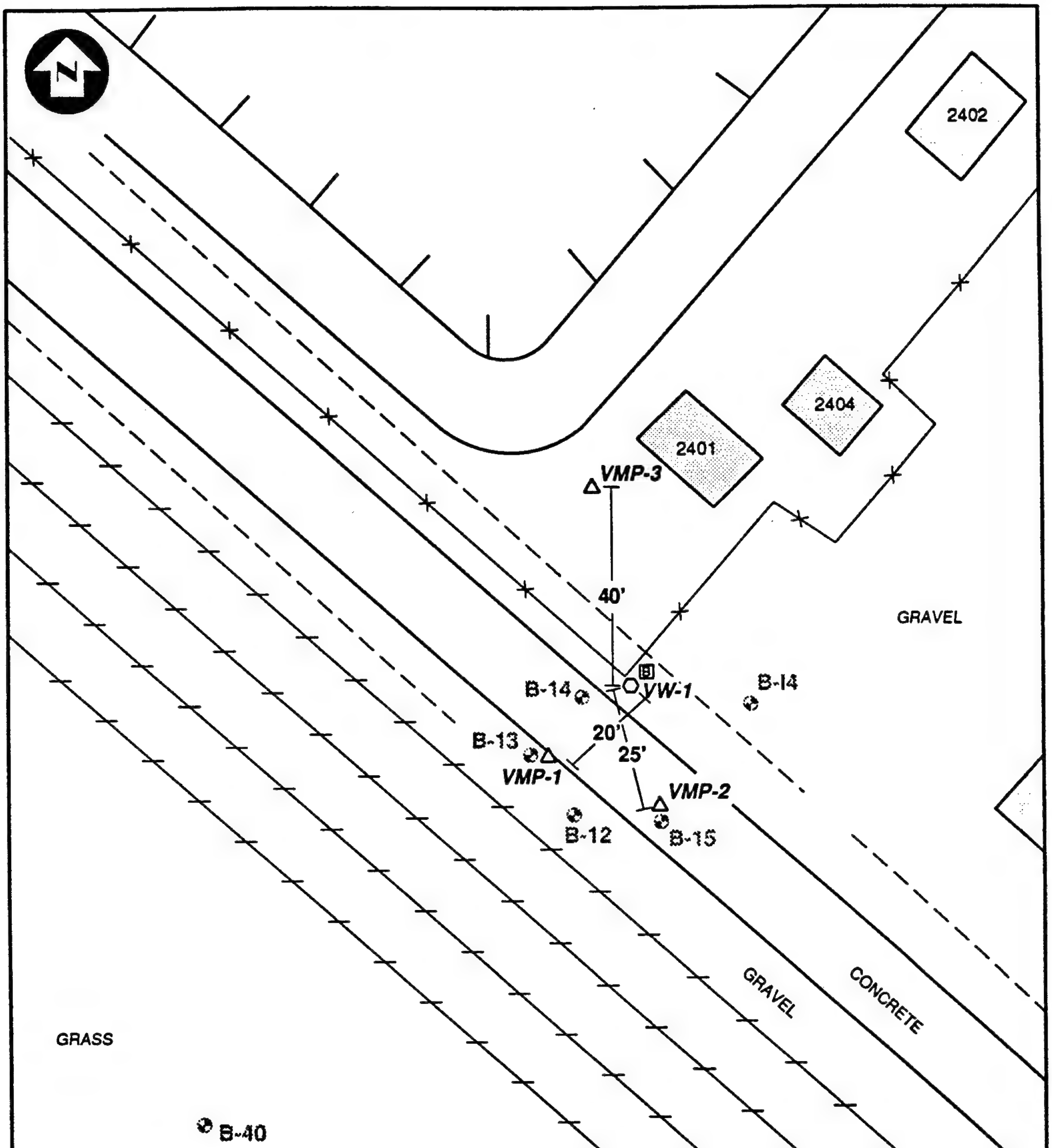
Figure 3.3 shows the proposed location of the blower, the central VW, and the VMPs for PS-1B. The VW location was chosen based upon the high degree of contamination observed in soil samples taken during the drilling of MW-208, the high levels of contamination found in soil gas in the same vicinity (see Table 2.3a and Table 2.3b), and the need to avoid subsurface utilities.

The radius of venting influence around the central VW is expected to be about 30 to 40 feet based upon the predominance of sands in contaminated subsurface soils at the site and upon the expected shallow depth of groundwater. The three VMPs are to be located at distances from the central VW which should provide adequate coverage over this expected radius of influence, yet still remain away from the numerous underground utilities in the area. Although Figure 3.3 shows three proposed VMPs, MW-208 will be used as VMP-2 in lieu of drilling at the VMP-2 location shown on Figure 3.3 in order to minimize drilling costs, if the water level measured in MW-208 at the time of drilling is below the top of the screened interval.

3.1.4 Building 2034

Figure 3.4 shows the proposed location of the blower, the central VW, and the VMPs for Building 2034. The VW location was chosen based upon the verbal description of contamination at the time of tank removal and the high level of contamination detected in the soil sample taken at the base of the excavation. In addition, the VW was located as far as practicable from the existing building to minimize the potential for vapor migration

FIGURE 3.2



EXPLANATION

B-40 SOIL BORING

B PROPOSED BLOWER LOCATION

VW-1 PROPOSED VENT WELL

VMP-1 PROPOSED VAPOR MONITORING POINT

FUEL LINES

FENCE

RAILROAD TRACKS

SOURCE: MODIFIED FROM ICF (1993b)

0 15 30

SCALE IN FEET

PROPOSED VENT WELL AND VAPOR MONITORING POINT LOCATIONS PS-1A

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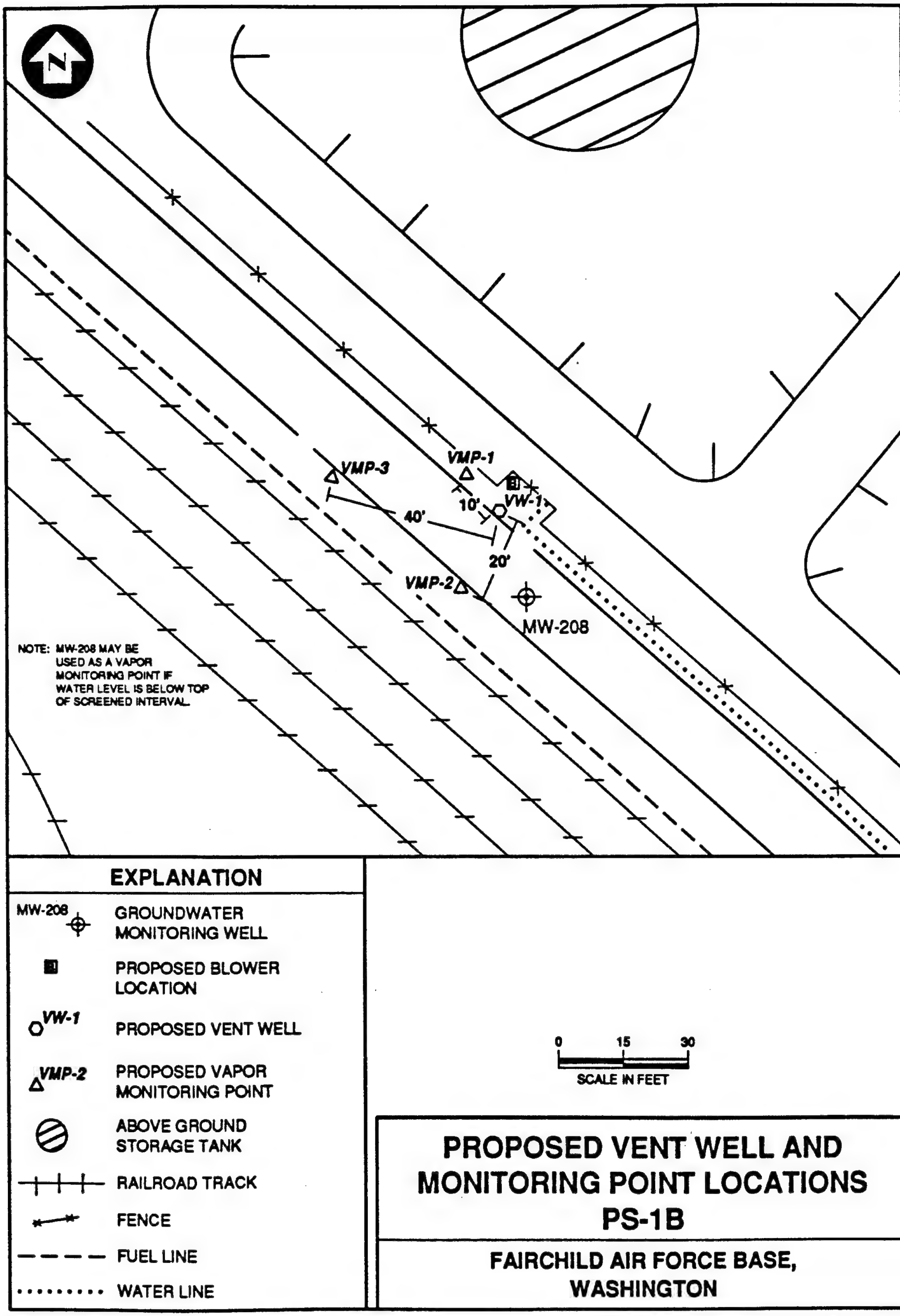
FIGURE 3.3



PROPOSED VENT WELL AND MONITORING POINT LOCATIONS PS-1B

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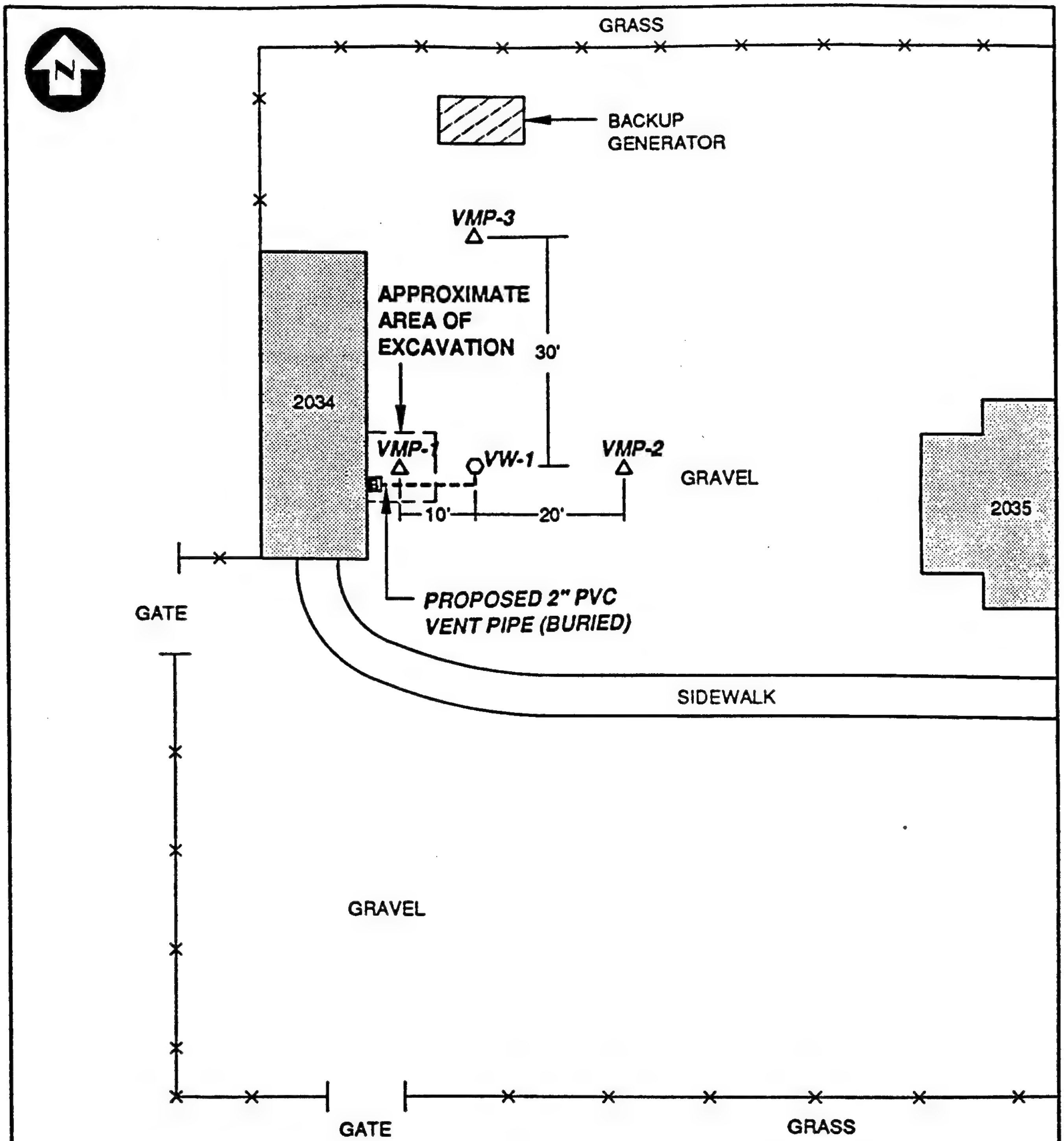
FIGURE 3.4



EXPLANATION

FENCE

PROPOSED BLOWER LOCATION

VW-1 PROPOSED VENT WELL

VMP-1 PROPOSED VAPOR MONITORING POINT

SOURCE: FAIRCHILD AFB (1993)

0 10 20

SCALE IN FEET

PROPOSED VENT WELL AND MONITORING POINT LOCATIONS BUILDING 2034

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into the building. During the pilot test, air in Building 2034 will be monitored with both a PID and Total Hydrocarbon Vapor Analyzer (THVA) to verify hazardous levels of vapors are not migrating into the building.

The radius of venting influence around the central VW is expected to be about 30 to 40 feet based upon the predominance of sands in subsurface soils at the site and upon the expected shallow depth of groundwater. One VMP will be located within the former excavation area to monitor conditions below the clean backfill. The other two VMPs will be located at distances from the central VW which should provide adequate coverage over the expected radius of influence and also further delineate the extent of contamination.

Due to the lack of soil analytical data and the extent of contamination, a soil-gas reconnaissance will be performed in this area prior to VW/VMP installation. The soil-gas will be measured with a hand-held O2/CO2 meter and THVA meter to look for areas of low oxygen and high TVH, which would indicate significant contamination. Results from this soil-gas reconnaissance may alter the proposed VW and VMP locations shown in Figure 3.4.

3.1.5 Building 2035

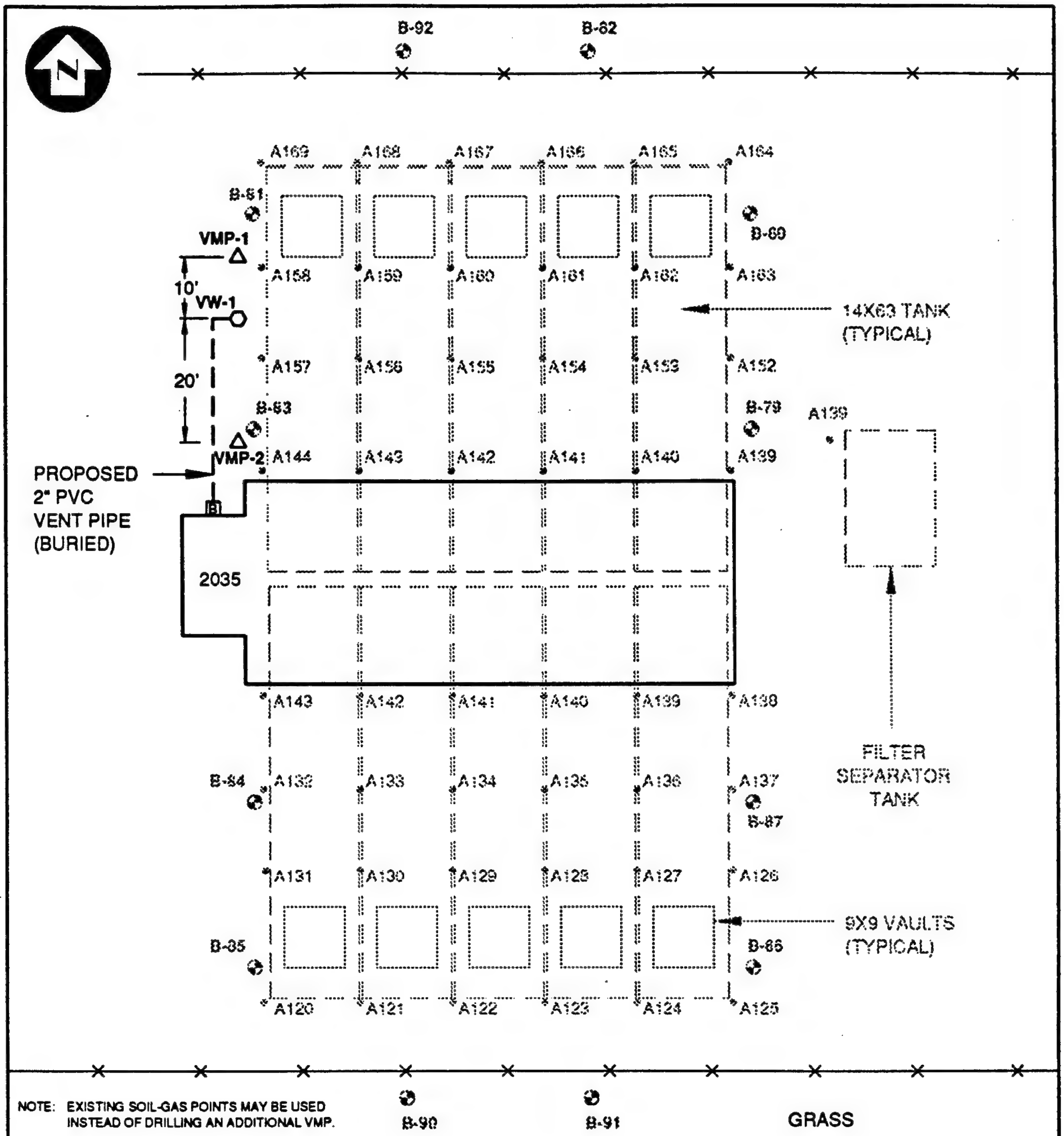
Figure 3.5 shows the proposed location of the blower, the central VW, and the VMPs for Building 2035. The VW location was chosen based upon the indication of contamination in soil boring B-83 and the levels of soil-gas contamination in locations A158, A159, and A168. In addition, the VW was located as far as practicable from the existing building to minimize the potential for vapor migration into the building. During the pilot test, air in Building 2034 will be monitored with both a PID and THVA to verify hazardous levels of vapors are not migrating into the building.

The radius of venting influence around the central VW is expected to be about 30 to 40 feet based upon the predominance of sands in subsurface soils at the site and upon the expected shallow depth of groundwater. Only two VMPs will be drilled at the site to minimize drilling costs. Some of the existing soil gas probes along the western tank boundary will be used as additional monitoring locations during the pilot test in lieu of drilling a third VMP.

Due to the lack of soil analytical data, a soil-gas reconnaissance will be performed in this area prior to VW/VMP installation. The soil-gas will be measured with a hand-held O2/CO2 meter and THVA meter to look for areas of low oxygen and high TVH, which would indicate significant fuel hydrocarbon contamination. Results from this soil-gas reconnaissance may alter the proposed VW and VMP locations shown in Figure 3.5.

3.1.6 Background VMPs

Two background vapor monitoring points will be installed as part of the initial pilot tests. The background VMPs will be used to measure background levels of oxygen and carbon dioxide and to determine if inorganic or natural carbon sources are contributing to the oxygen uptake during the *in situ* respiration tests (described in Section 3.8). Existing monitoring wells which have a portion of their screened interval above the water table



EXPLANATION

FENCE

B-13 SOIL BORING

*A120 SOIL GAS SAMPLE LOCATION

UNDERGROUND FUEL STORAGE TANK

PROPOSED BLOWER LOCATION

VW-1 PROPOSED VENT WELL

VMP-2 PROPOSED VAPOR MONITORING POINT

SOURCE: MODIFIED FROM HALLIBURTON NUS (1993)

0 12.5 25

SCALE IN FEET

PROPOSED VENT WELL AND VAPOR MONITORING POINT LOCATIONS BUILDING 2035

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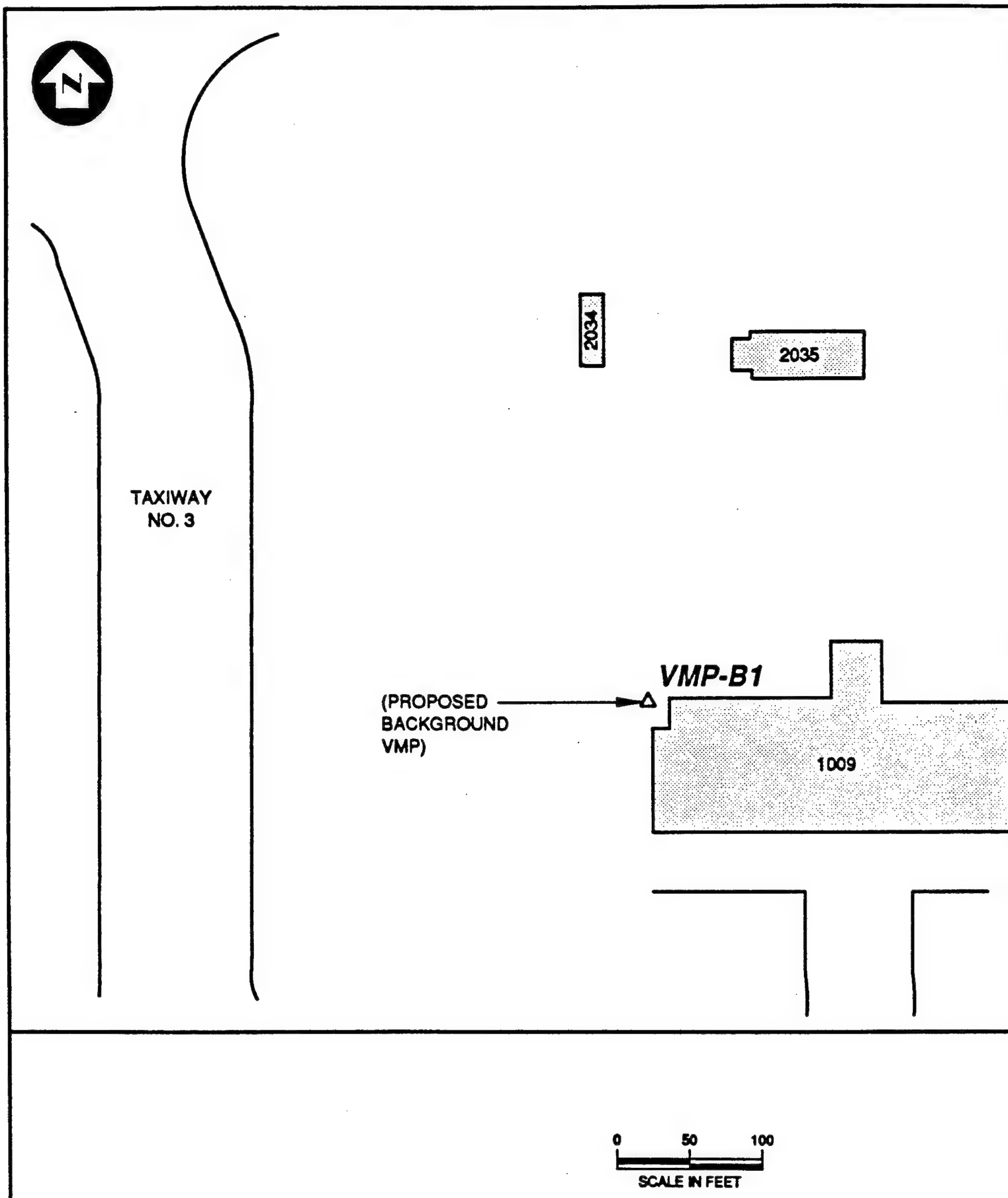
FIGURE 3.6



PROPOSED BACKGROUND VMP LOCATION
PS-2
BUILDING 2034, BUILDING 2035

FAIRCHILD AIR FORCE BASE,
WASHINGTON

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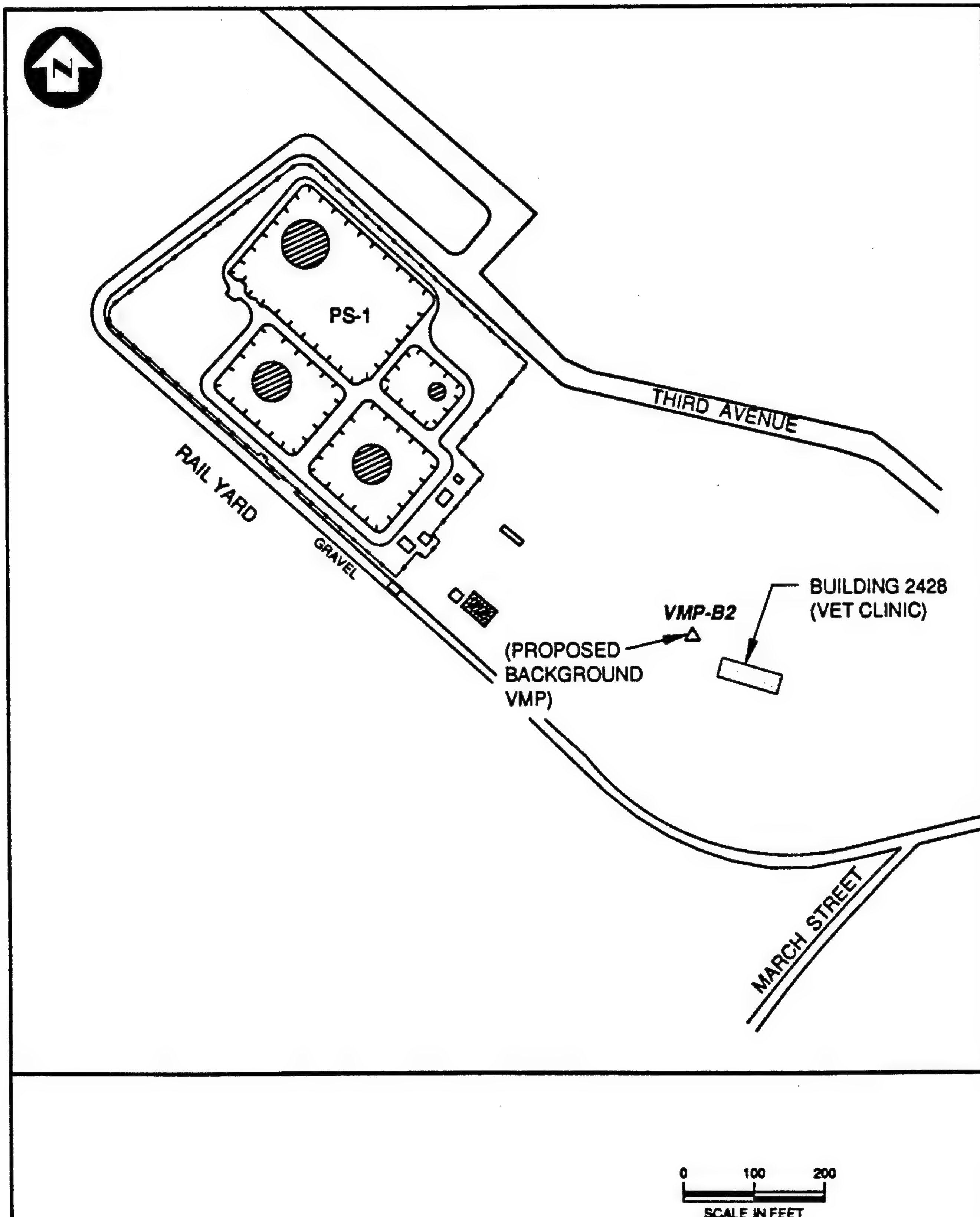

PROPOSED BACKGROUND VMP LOCATION PS-1 AND PS-1B

FAIRCHILD AIR FORCE BASE, WASHINGTON

SOURCE: MODIFIED FROM FAIRCHILD AFB (1993)

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can potentially be used as background VMPs. However, at Fairchild AFB all existing monitoring wells are either too far away from the bioventing sites, are screened inappropriately, or have historical evidence of contamination.

One background VMP (VMP-B1) will be installed adjacent to Building 1009 along the eastern part of the flightline, 300 feet south of the bioventing sites at Building 2034 and Building 2035 (Figure 3.6). This background VMP will be used during the respiration tests conducted at sites PS-2, Building 2034, and Building 2035 where soil types are expected to be similar. The location is not within any known contaminated area; however, if contamination is observed during drilling, a field decision will be made to choose an alternate location or to use the background VMP at PS-1 (described below) for the three flightline bioventing sites.

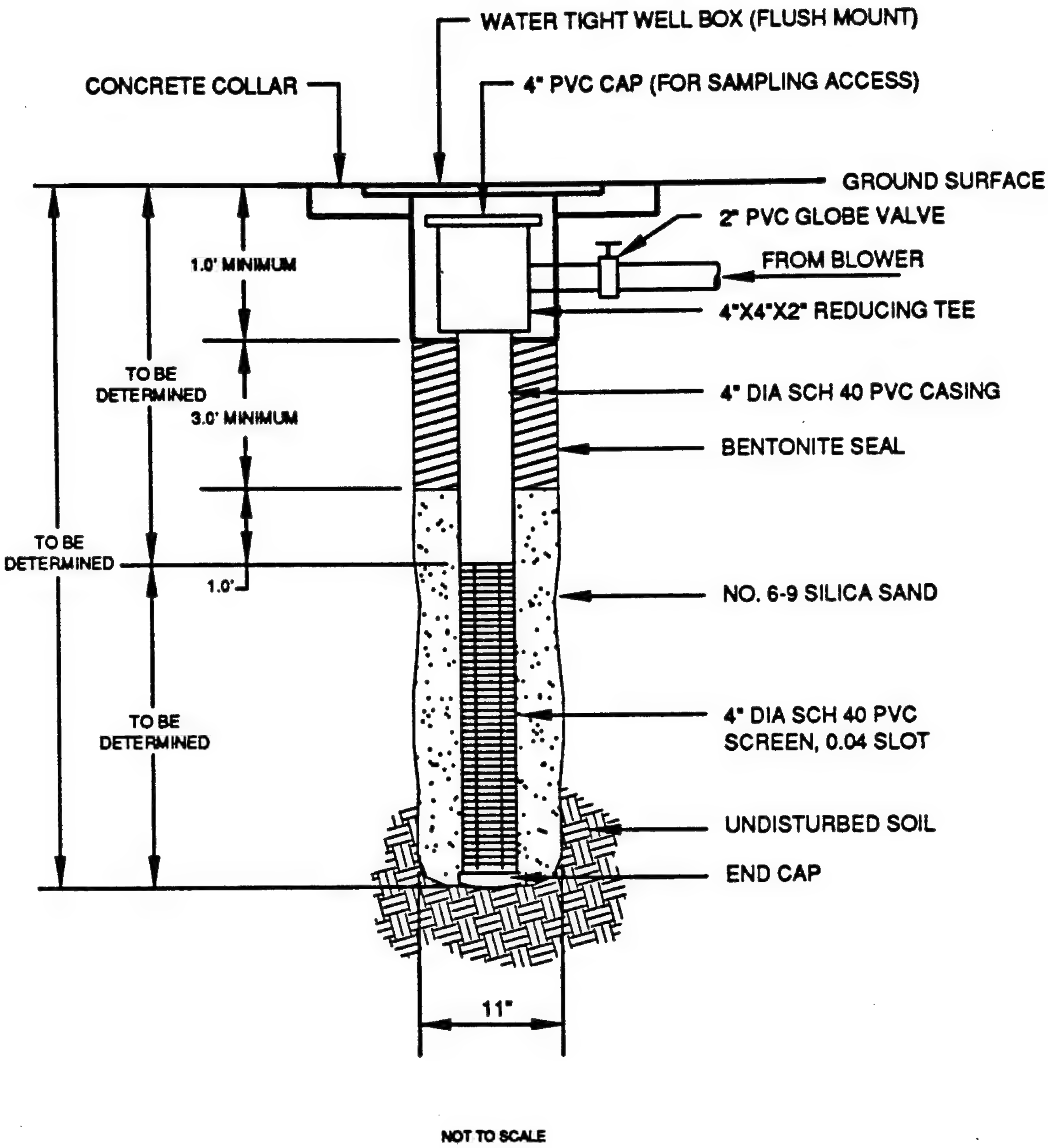
The second background VMP (VMP-B2) will be installed approximately 400 feet southeast of PS-1, adjacent to Building 2428, the base vet clinic (Figure 3.7). This background VMP will be used during the respiration tests conducted at sites PS-1A and PS-1B, where soil types are expected to be similar. The location is not within any known contaminated area.

3.2 Construction of Vent Wells

A typical construction diagram for the central VW at each site is shown in Figure 3.8. The central VW will be constructed of 4-inch ID schedule 40 PVC casing, with an interval of 0.04-inch slotted screen typically set between the initially encountered contamination (but a minimum of 4 feet bgs) down to the base of contamination as determined by field organic vapor analysis (OVA) of soil sample head space. The top of the screened interval may be set lower than the uppermost zone of soil contamination to prevent short-circuiting of injected air to an uncovered ground surface or within excavation fill material. The bottom of the screened interval may be set above the base of contamination to prevent preferential flow within less contaminated, but significantly more permeable zones, or to prevent situations which would cause an undesirable water level within the VW.

A 100 ppmv OVA reading will be the criterion used in determining the selected depths. A GasTech™ Total Hydrocarbon Vapor Analyzer (THVA) will be used to collect field OVA readings. This platinum catalyst combustion detector is calibrated with hexane, which provides a conservative reading representative of total petroleum hydrocarbon vapors present (refer to Section 4.5.2 of the protocol document).

Flush-threaded PVC casing and screen will be used with no organic solvents or glues. The filter pack will be clean silica sand with a 6-9 grain size (or equivalent) and will be placed in the annular space of the screened interval. A 3-foot layer of bentonite will be placed directly over the filter pack. The remainder of the annular space, except for a 1-foot open area directly below the ground surface, will be filled with a bentonite/cement grout. A complete seal is critical to prevent the short circuiting of air to the surface during injection.



NOTE: DEPTH OF SCREENED INTERVAL WILL BE NEAR THE BASE OF CONTAMINATION AS DETERMINED IN THE FIELD.

VENTING WELL CONSTRUCTION DIAGRAM (TYPICAL)

FAIRCHILD AIR FORCE BASE, WASHINGTON

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During pilot testing, the blower will be connected to the VW through 2-inch diameter PVC pipe buried approximately 1 foot below the ground surface (see Figures 3.1 through 3.5).

Additional details on VW construction are found in Section 4 of the protocol document.

3.3 Construction of Vapor Monitoring Points

A typical construction diagram for the multi-depth VMPs at each site is shown in Figure 3.9. Soil-gas oxygen and carbon dioxide concentrations will be monitored via vapor monitoring screens placed at depth intervals which provide good vertical coverage between the ground surface and the base of contamination. Multi-depth monitoring will determine the concentration of oxygen across the entire soil profile and will be used to calculate oxygen utilization rates and fuel biodegradation rates at all monitored depths. The annular space between the vapor monitoring screen filter packs will be sealed with bentonite to isolate the monitoring intervals. As with the central VW, several inches of bentonite pellets will be used to shield the filter pack intervals from rapid infiltration of bentonite slurry additions. At the innermost vapor monitoring point (VMP-1), thermocouples will be installed at the same depths as the deepest and shallowest screens to measure soil temperature.

Additional details on VMP construction are found in Section 4 of the protocol document.

3.4 Handling of Drill Cuttings

All drill cuttings will be gathered after each borehole is drilled and containerized on a site-specific basis at each site in labelled U.S. DOT-approved 55 gallon drums. These soils will be handled according to protocol outlined in the base Soil Management Plan.

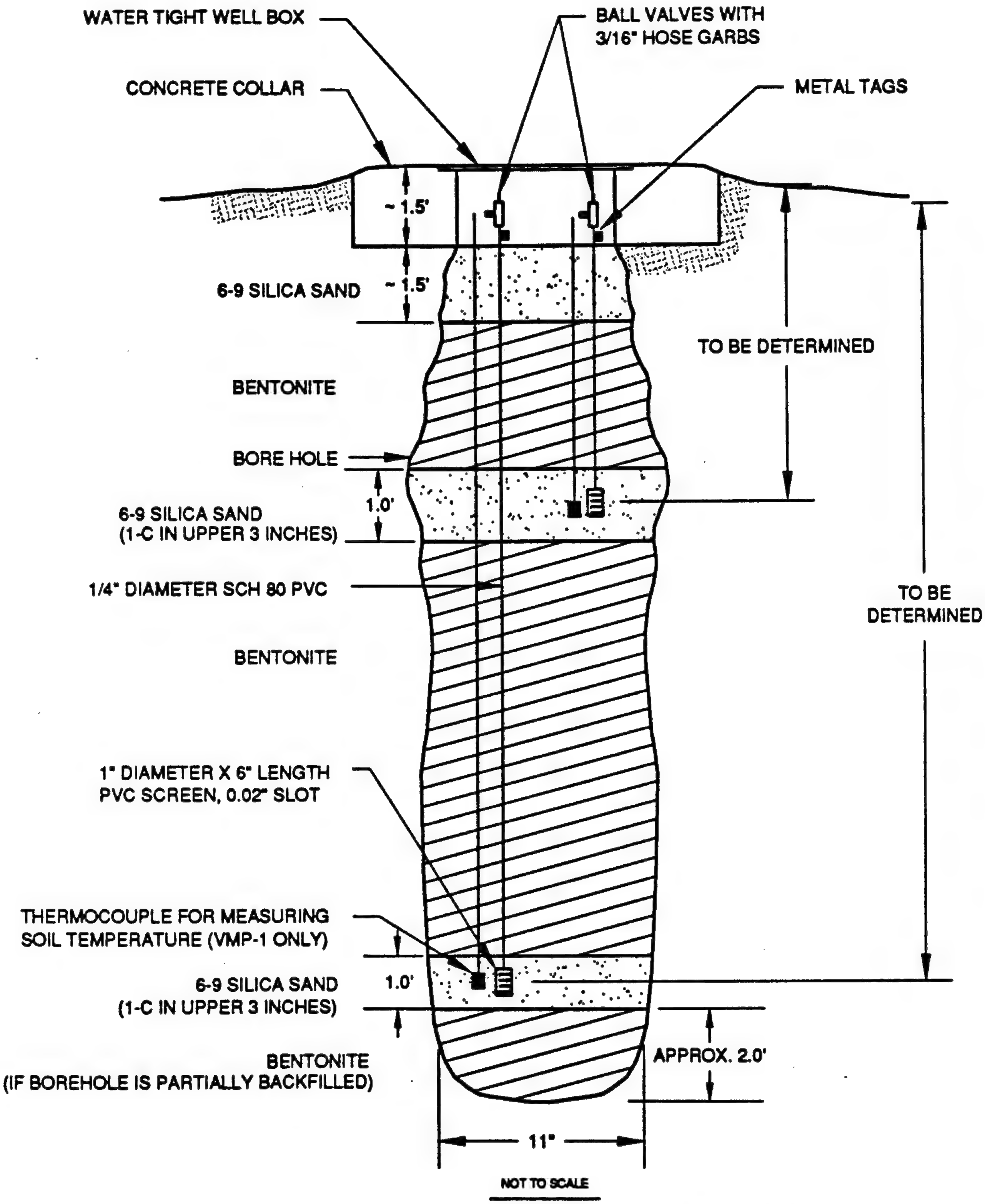
3.5 Soil and Soil-Gas Sampling

3.5.1 Soil Sampling

Three soil samples will be collected from each site during the installation of the central VW and VMPs. One sample will be collected from the most contaminated interval of the central VW boring, and one sample will be collected from the most contaminated interval in each of the two innermost borings (VMP-1 and VMP-2). Soil samples will be analyzed for total recoverable petroleum hydrocarbons (TRPH), benzene, toluene, ethylbenzene, and xylenes (BTEX), soil moisture, pH, grain size distribution, alkalinity, total iron, and nutrients including total Kjeldahl nitrogen (TKN) and total phosphorus.

Additional soil samples will be collected at each of the background VMPs and analyzed for TKN to help characterize the non-contaminated, baseline soil nutrient conditions.

Soil samples will be collected using a split-spoon sampler containing brass tube liners. Soil samples collected in the brass tubes will be immediately trimmed and the ends sealed with Teflon® fabric held in place by plastic caps. Soil samples collected for



NOTE: DEPTH TO SCREENS WILL BE DETERMINED IN THE FIELD BASED ON OBSERVED CONTAMINATION.

VAPOR MONITORING POINT CONSTRUCTION DIAGRAM (TYPICAL)

FAIRCHILD AIR FORCE BASE, WASHINGTON

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inorganic and physical parameters analysis will be collected in brass tubes or placed in other appropriate sample containers. Soil samples will be labeled following the nomenclature specified in Section 5.5 of the protocol document, wrapped in plastic, and placed in an ice chest for shipment. A chain-of-custody form will be filled out and the ice chest shipped for analysis to a laboratory that has been audited by the U.S. Air Force and which meets all quality assurance/quality control and certification requirements.

3.5.2 Soil-Gas Sampling

A total hydrocarbon vapor analyzer (THVA) will be used to screen split-spoon samples during drilling for determination of the most contaminated intervals. During the pilot test at each site, initial and final soil-gas samples at each site will be collected in Summa® cannisters from the central VW (VW-1) and the VMPs closest to and furthest from the central VW (VMP-1 and VMP-3). These soil-gas samples will be used to predict potential air emissions and to determine the reduction in BTEX and total hydrocarbons.

Soil-gas samples will be packed to prevent excessive movement during shipment. Samples will not be sent on ice in order to prevent condensation of hydrocarbons. Samples will be analyzed for BTEX and total volatile hydrocarbons (TVH) using EPA Method TO-3. A chain-of-custody form will be filled out and the samples shipped to Air Toxics, Ltd. in Folsom, California for analysis.

3.5.3 Potential Air Emissions Monitoring

In order to characterize potential air emissions during the pilot test, soil-gas samples will also be taken at the ground surface for the two sites not covered by asphalt or concrete (Building 2034 and Building 2035). Total volatile hydrocarbons (TVH) will be measured at the ground surface before and during air injection at 5 locations at both of the sites. Three of the measurement locations will be arranged around the injection well spaced roughly 120° apart and located at a distance of 1/3 of the expected radius of venting influence. Air emissions, if present, would be expected to be highest nearest the vent well. The remaining two measurement locations will be spaced at distances of 2/3 of the radius of influence and at the full radius of influence to characterize the areal extent of any emissions.

Hydrocarbon emissions will be measured using both field and laboratory analysis. TVH will be measured in the field by placing an emission isolation flux chamber on the ground surface and then withdrawing soil-gas samples at a rate of approximately one liter per minute into the THVA. The flux chamber design and operation will follow protocols developed by the Environmental Protection Agency's Environmental Monitoring Systems Laboratory (EMSL) (Kienbusch, USEPA 1986). Air in the flux chamber will be sampled continuously for 4 residence times (approximately 24 minutes) at each location and the readings will be recorded in the field notebook.

To further characterize the fuel hydrocarbon and BTEX content of the any soil-gas emissions, two soil-gas samples for laboratory analysis will be taken from a measurement location nearest the injection well. The first sample will be taken prior to air injection and used to characterize background emissions. The second sample will be taken after

four hours of air injection. These samples will be collected using an evacuated, one liter Summa® cannister to draw a sample from the flux chamber. The samples will be shipped and analyzed as described in Section 3.5.2.

3.6 Blower System

A 3.0 horsepower, portable, positive displacement blower capable of injecting air at approximately 40 standard cubic feet per minute (scfm) at 4 psi (110 inches H2O) will be used to conduct the initial air permeability test at each site. Figure 3.10 is a schematic of a typical air injection system used for pilot testing. The maximum power requirement anticipated for pilot testing is 208 volt, single-phase, 30 amp service.

Important additional details on power supply requirements and fire safety codes are described in Section 5.0, Base Support Requirements.

3.7 Air Permeability Tests

The objective of the air permeability test is to determine the extent of the subsurface which can be oxygenated using one air injection unit. Air will be injected into the 4-inch diameter central VW at each site using the portable blower unit, and the pressure response will be measured at each VMP with differential pressure gauges to determine the region influenced by the unit. Oxygen will also be monitored in the VMPs to ascertain that oxygen levels in the soil increase as a result of air injection. One air permeability test lasting approximately 4 to 6 hours will be conducted at each site.

Additional details on the air permeability test are found in Section 5.6 of the protocol document.

3.8 *In Situ* Respiration Tests

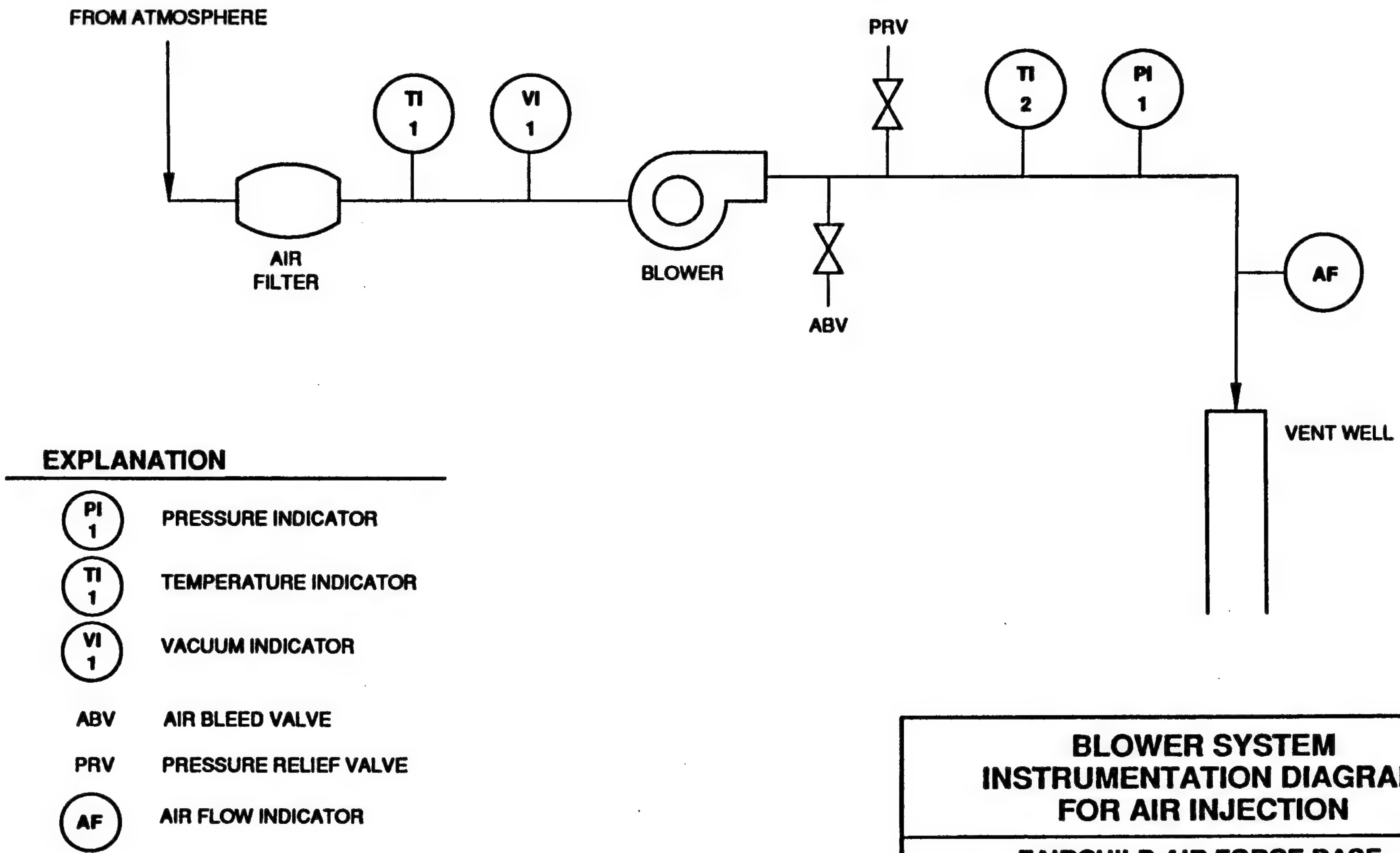
The objective of the in situ respiration test is to determine the rate at which soil bacteria will biodegrade the TPH contamination in the soil. At each site, respiration tests will be performed at vapor monitoring screens where bacterial degradation is indicated by initially low oxygen levels and elevated carbon dioxide levels in the soil gas. Air will be injected at points containing low oxygen levels (below approximately 5 percent) for approximately 20 hours to oxygenate local contaminated soils. At the end of the 20-hour period, the air supply will be cut off and oxygen, carbon dioxide, and TVH levels will be monitored for the following 24 to 72 hours. The decline in oxygen levels over time will be used to estimate rates of bacterial degradation of fuel residuals.

Respiration tests will also be conducted at any background VMP which shows initial oxygen levels below 18% in order to correct biodegradation rates for inorganic or natural carbon source uptake of oxygen.

Helium, an inert gas, will be injected at a concentration of 2 to 4 percent into vapor monitoring points used for respiration testing. The helium will be used as a tracer gas and levels will be monitored during the respiration test to identify possible system leaks or short circuits to the surface.

Additional details on *in situ* respiration testing are found in Section 5.7 of the protocol document.

FIGURE 3.10



BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR INJECTION

FAIRCHILD AIR FORCE BASE, WASHINGTON

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3.9 Installation of Extended Bioventing Pilot Test Systems

An extended (one-year) bioventing pilot test system will be implemented at each site if the initial pilot test successfully demonstrates the feasibility of providing oxygen throughout the contaminated soil profile. This one year of continuous air injection will determine the long-term radius of influence, and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates. A fixed Gast™ regenerative blower unit, sized appropriately for each site, will be installed as part of this extended pilot test system. The blower will be housed in a small shed to provide protection from the weather and to minimize noise. This small "doghouse" will be located in a low-traffic area.

The systems will be in operation for one year, and ES personnel will monitor them biannually, scheduled for May 1994 and November 1994. This biannual monitoring will consist of *in situ* respiration tests at each site to monitor the long-term performance of the bioventing systems. Additionally, at the end of the extended (one-year) test, subsurface soil and soil-gas samples will be collected and analyzed at locations as close as possible to the original VW/VMP soil and soil-gas sample locations at each site in order to assess the degree of remediation during the first year of in situ treatment.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The procedures that will be used at each site to construct wells, measure air permeability of the soil, and conduct the *in situ* respiration tests are described in Section 4 and 5 of the protocol document. No significant exceptions to the protocol are anticipated.

5.0 BASE SUPPORT REQUIREMENTS

The following base support is needed prior to the arrival of the drillers and the ES test team:

- Installation of a 208V/single phase/30 amp breaker box, which meets any locally or Air Force required fire safety codes. The breaker box must include an on-off switch, one 208V receptacle (NEMA type L630 for sites not requiring explosion-proof plugs), and at least one 110V receptacle. This breaker box must be within 20 feet of the proposed blower location at each site (Figures 3.1 through 3.5).
- Obtaining all necessary regulatory permits for the vent wells and vapor monitoring points, including any air permits needed for pilot test approval.
- Provide a copy of any base soils management plan (SMP) and/or sampling and analytical procedures (SAP) plan.
- Obtaining a base digging permit.
- Provide any paperwork required to obtain gate passes and security badges for drilling personnel and four ES employees. If required by the base, vehicle passes will be needed for two ES trucks, two drill rigs, and two drilling support trucks. These passes must be valid for the expected duration of drilling operations (about 4 weeks) and the five pilot tests (about 6 weeks).
- Provide keys to all on-site groundwater monitoring wells.

During the initial pilot tests (a 6-week period), the following base support is required:

- 12 square feet of desk space and use of a telephone.
- Use of a fax machine for transmitting pilot test results.
- A decontamination area where the drillers can clean drilling equipment between sites.

During the extended (one-year) pilot test, the following base support is required:

- Base personnel are to check the blower systems once each week to ensure that they are all operating, record air injection pressures and temperatures, and replace air filters, as needed. ES will provide a maintenance procedures manual and a brief training session.
- If any blowers stop working, notify: Mr. Fred Stanin or Mr. Michael Phelps, ES-Alameda, (510) 769-0100; or Mr. Doug Downey, ES-Denver (303) 831-8100; or Mr. Patrick Haas of AFCEE, (210) 536-4314.
- Arrange for site access for ES technicians to conduct *in situ* respiration tests at approximately six months and one year after the initial pilot tests.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan.

Event	Date
Draft Pilot Test Work Plan to AFCEE/Fairchild AFB	24 Aug 1993
Approval to Proceed	10 Sep 1993
Begin VW and VMP construction	13 Sep 1993
Begin Initial Pilot Tests	4 Oct 1993
Completion of Initial Pilot Tests	19 Nov 1993
Interim Results Report	February 1994
Biannual Respiration Tests	May 1994
Final Respiration Tests and Soil Sampling	November 1994

7.0 POINTS OF CONTACT

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Alameda, CA 94501
(510) 769-0100
Fax (510) 769-9244

8.0 REFERENCES

Halliburton NUS 1993, Feasibility Study Report Priority One Operable Units (Final). February

Hinchee et al. 1992, Test Plan and Technical Protocol for a Field Treatability Test for Bioventing, U.S. Air Force Center for Environmental Excellence (AFCEE). January

ICF 1993a, Remedial Investigation/Feasibility Study Work Plan for Priority Two Sites (Draft Final). January

ICF 1993b, Remedial Investigation/Feasibility Study for Priority Two Sites (pre-Draft and verbal communications). July

Kienbusch, M. R. 1986, Measurement of Gaseous Emission Rates from Land Surface Using an Emission Isolation Flux Chamber: User's Guide, EPA/600/8-86/008, USEPA EMSL. February

Rittenhouse-Zeman & Associates (RZA) 1988, Underground Storage Tank Study Phase I. January

Science Applications International Corporation (SAIC) 1990, Site Characterization Summary Priority One Sites. December

Tracer Research Corporation 1989, Soil Gas Survey Results Job# J-920-89-LO dated 10/24/89 (untitled).

PART II

Draft
Bioventing Pilot Test Interim Results Report for

PS-2, PS-1A, PS-1B, BUILDING 2034, BUILDING 2035
FAIRCHILD AIR FORCE BASE, WASHINGTON

Prepared for

Air Force Center for Environmental Excellence
Brooks AFB, Texas
and
Fairchild Air Force Base, Washington

June 1994

Prepared by

ENGINEERING-SCIENCE, INC.
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PART II

DRAFT BIOVENTING PILOT TEST INTERIM RESULTS REPORT FOR
PS-2, PS-1A, PS-1B, BUILDING 2034, BUILDING 2035
Fairchild Air Force Base, Washington

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PART II
DRAFT BIOVENTING PILOT TEST INTERIM RESULTS REPORT FOR PS-2, PS-1A, PS-1B, BUILDING 2034, AND BUILDING 2035
Fairchild AFB, Washington

Initial bioventing pilot tests were completed at five sites at Fairchild Air Force Base, Washington (Fairchild AFB): PS-2, PS-1A, PS-1B, Building 2034, and Building 2035. Two background vapor monitoring points were installed, one near the PS-1A and PS-1B sites and one near the flightline south of Building 2035. The purpose of this Part II Interim Report is to describe the results of the initial pilot tests at each site and make specific recommendations for the extended (one-year) pilot tests which will determine the long-term impact of bioventing on site contaminants. Site histories, known contamination distributions and concentrations, and geologic/hydrogeologic profiles are documented in Part I, Bioventing Pilot Test Work Plan.

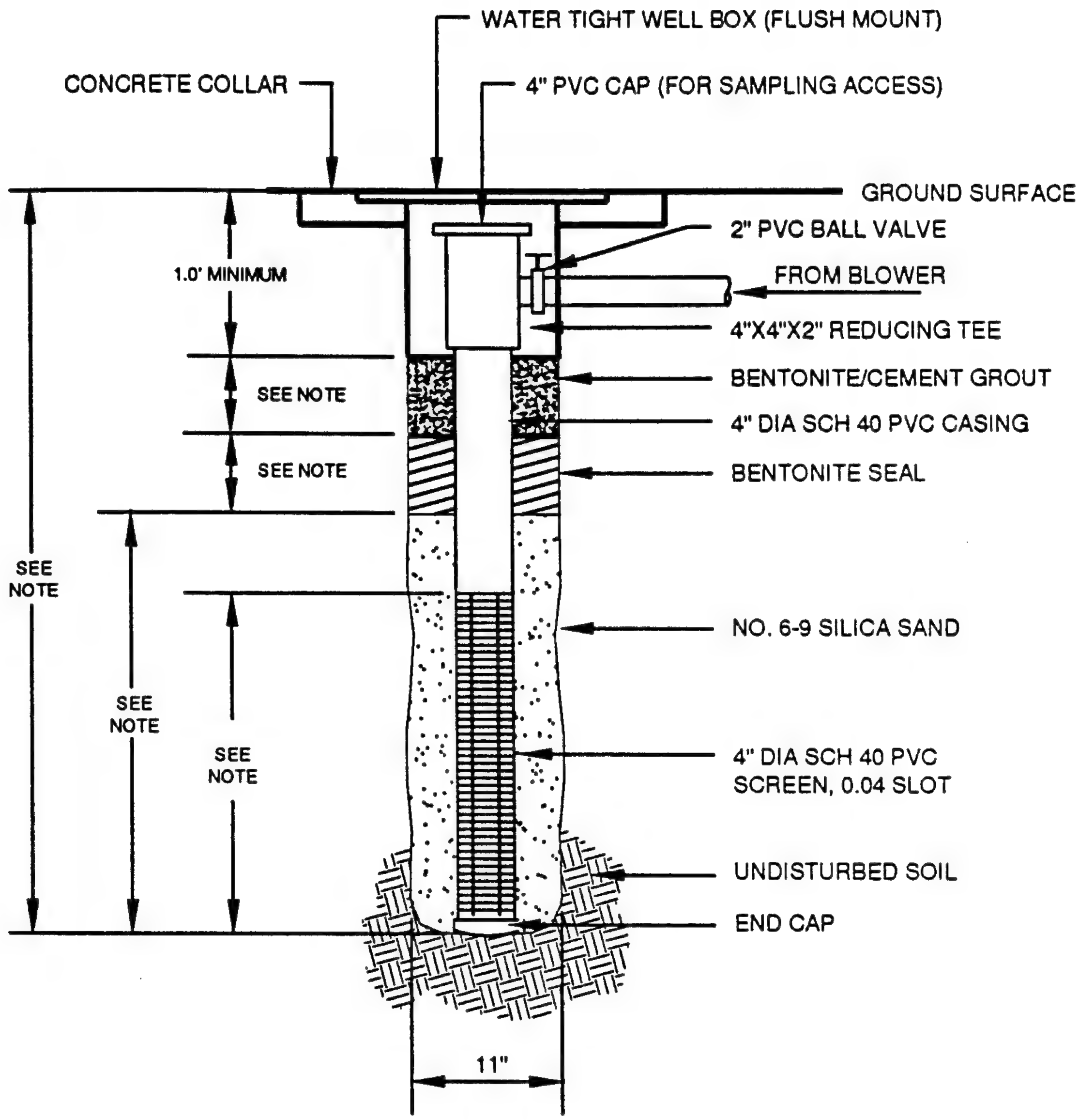
1.0 PILOT TEST DESIGN AND CONSTRUCTION

1.1 Vent Well Construction

Five vent wells (VWs) were installed as part of drilling activities. One air injection VW was installed at each site in a location where soils exhibited a noticeable fuel odor following procedures described in the protocol document (Hinchee et al., 1992). Borehole drilling services were provided by Environmental West Exploration, Inc. of Spokane, Washington. Soil sampling and well installation was directed at each site by Mr. S. Thomas Taylor of the Engineering-Science, Inc. (ES) office in Richland, Washington.

Each VW was constructed using 4-inch inside diameter (ID), Schedule 40 PVC casing and slotted screen (0.040-inch slot size). The annular space adjacent to the screen was filled with 6-9 sieve size silica sand (filter pack material) from the bottom of the screen to approximately 0.5 feet above the top of the screen. A small amount of 100 mesh silica sand was added to the top of this interval to inhibit penetration of the overlying bentonite seal material into the filter pack interval.

To prevent preferential air movement near the surface during pilot testing, a 2-foot thick annular bentonite seal was emplaced on top of the filter pack. The annulus of the well was then filled with a bentonite/cement grout to approximately 2 feet bgs. The upper 2 feet of annular space was left vacant for ease of connecting subsurface piping for pilot testing and possible future full-scale remediation system implementation. The upper 2 feet of well casing was completed with a 4-inch diameter Schedule 40 PVC tee and a 4-inch PVC cap. The typical as-built construction detail for the VWs is shown on Figure 1.1. Further details on the VW installed at each site are included in the site-specific sections (Sections 1.4 through 1.8).



NOT TO SCALE

NOTE: WELL CONSTRUCTION DETAILS CAN BE FOUND IN FOLLOWING TABLES.

SITE	WELL DETAILS
PS-2	TABLE 1.2
PS-1A	TABLE 1.4
PS-1B	TABLE 1.6
BUILDING 2034	TABLE 1.8
BUILDING 2035	TABLE 1.10
BACKGROUND WELLS	TABLE 1.12

VENTING WELL CONSTRUCTION DIAGRAM (TYPICAL)

FAIRCHILD AIR FORCE BASE, WASHINGTON

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Soil samples from split-spoon and/or continuous soil samplers were collected for field organic vapor analysis (OVA) to determine appropriate VW screened intervals and total depths. Both a total hydrocarbon vapor analyzer (THVA) and a photoionization detector (PID) were used to screen field samples. Soil samples were also collected for laboratory analysis. Analytical results are discussed in Section 2.0.

1.2 Vapor Monitoring Point Construction

Seventeen (17) vapor monitoring points (VMPs) were installed as part of drilling activities, three at each of the five bioventing sites and two background VMPs. Each VMP was constructed using 0.25-inch ID, Schedule 80 PVC casing and 1-inch ID slotted screen intervals (0.020-inch slot size). Two casing strings/screens were installed in each VMP borehole to provide monitoring points at variable depths and contamination levels.

Each of the screened intervals was 6 inches in length at the bottom of each individual PVC casing string and was centered in a 1-foot thick layer of 6-9 sieve size silica sand (filter pack material) topped with a thin layer of 100 mesh silica sand. These filter pack intervals were sealed above and below with bentonite. A sampling valve was attached to the top of each casing string. In one of the VMPs at each site (typically VMP-1), two thermocouples were installed adjacent to the screens at the shallowest and deepest depths to allow measurement of soil temperature.

The typical as-built construction detail for the VMPs is shown on Figure 1.2. Further details on the VMPs installed at each site are included in the site-specific sections (Sections 1.4 through 1.8).

1.3 Blower Units

At each of the five sites, a portable 3.0-horsepower (HP) Roots™ positive displacement blower unit, powered by a 20-kilowatt (KW) generator, was used for the initial pilot test. A fixed 1.0-HP Gast™ regenerative blower unit (model R4) was installed for the extended pilot test. Figure 1.3 shows the typical process flow and instrumentation diagram for each system. Further details on the air injection flow rates used for each site are included in the site-specific sections (Sections 1.4 through 1.8).

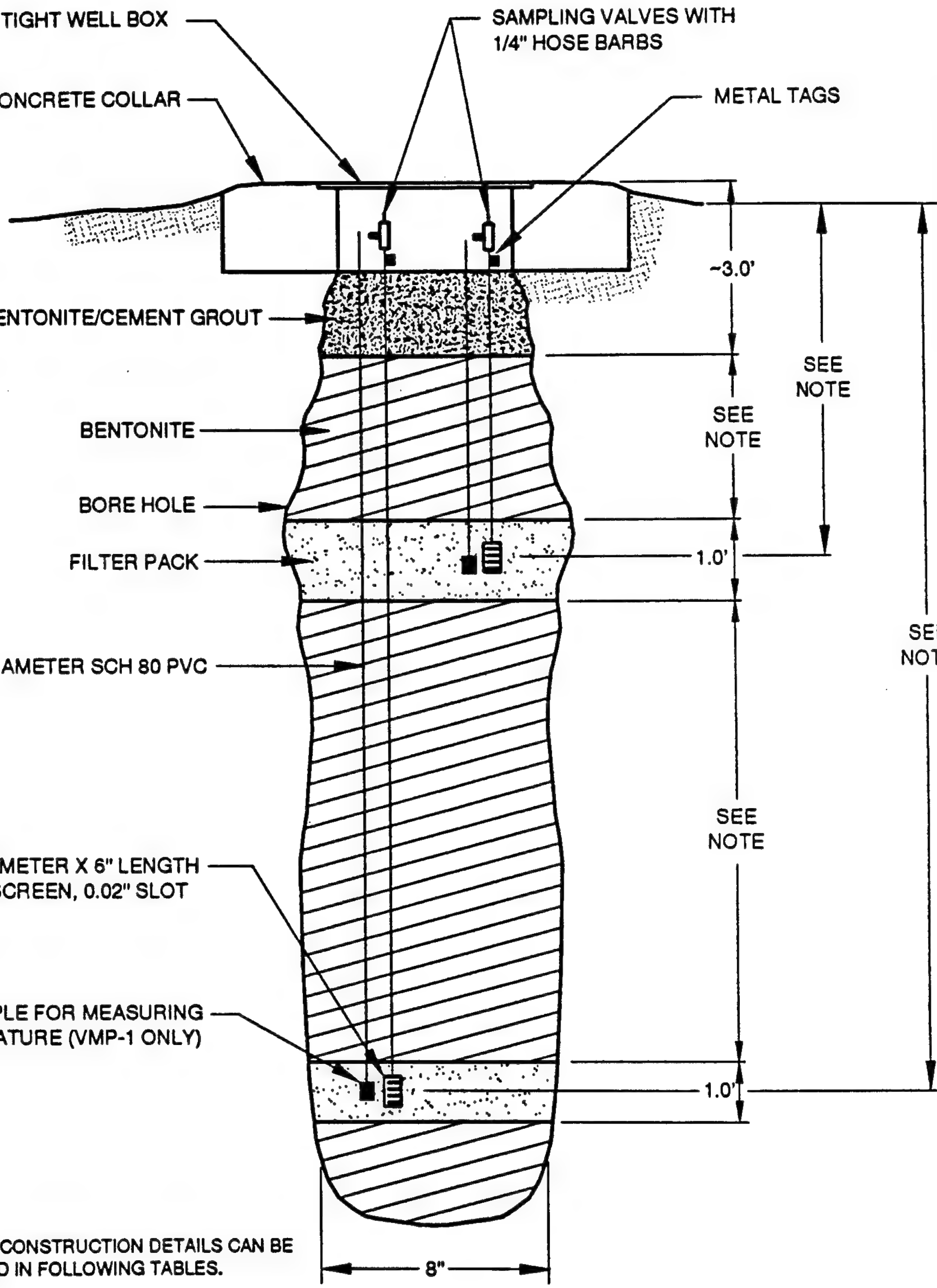
ES personnel provided an operations and maintenance (O&M) data collection sheet and blower maintenance manual for each site to base personnel. A sample copy of the data collection sheet and maintenance manual is provided in Appendix B.

1.4 PS-2

1.4.1 Introduction

Installation of one VW (VW-1) and three VMPs (VMP-1, VMP-2, and VMP-3) was conducted at PS-2 between 22 and 28 September 1993. Locations of the VWs and VMPs are shown on Figure 1.4.

Six boreholes were drilled at the site and four were converted to either a VW or a VMP. Two boreholes were abandoned. Borehole #4 was abandoned because a large boulder was encountered at 6 feet below ground surface (bgs) and borehole #6 was



NOTE: WELL CONSTRUCTION DETAILS CAN BE FOUND IN FOLLOWING TABLES.

NOT TO SCALE

SITE	WELL DETAILS
PS-2	TABLE 1.2
PS-1A	TABLE 1.4
PS-1B	TABLE 1.6
BUILDING 2034	TABLE 1.8
BUILDING 2035	TABLE 1.10
BACKGROUND WELLS	TABLE 1.12

AS-BUILT VAPOR MONITORING POINT CONSTRUCTION DETAIL (TYPICAL)

FAIRCHILD AIR FORCE BASE, WASHINGTON

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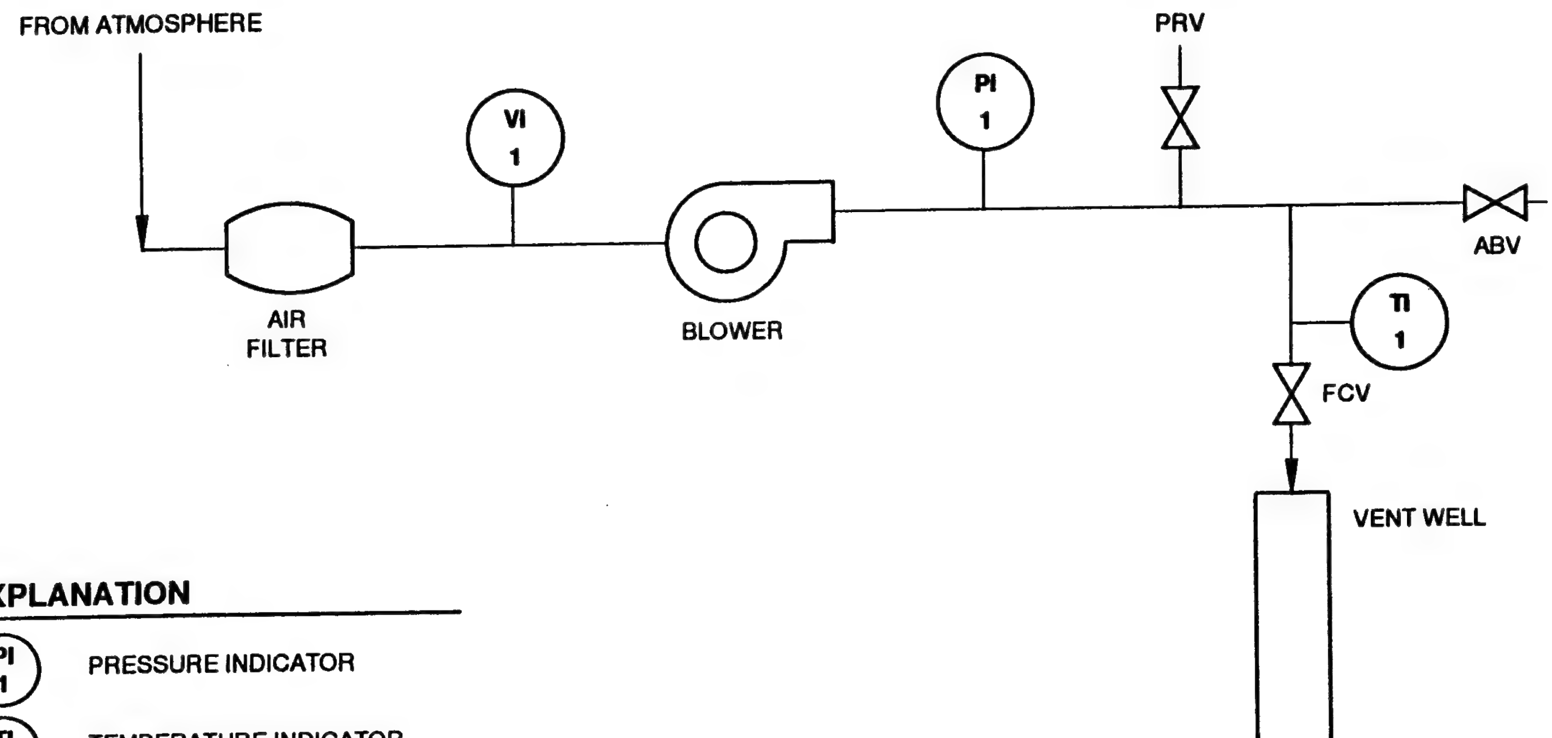


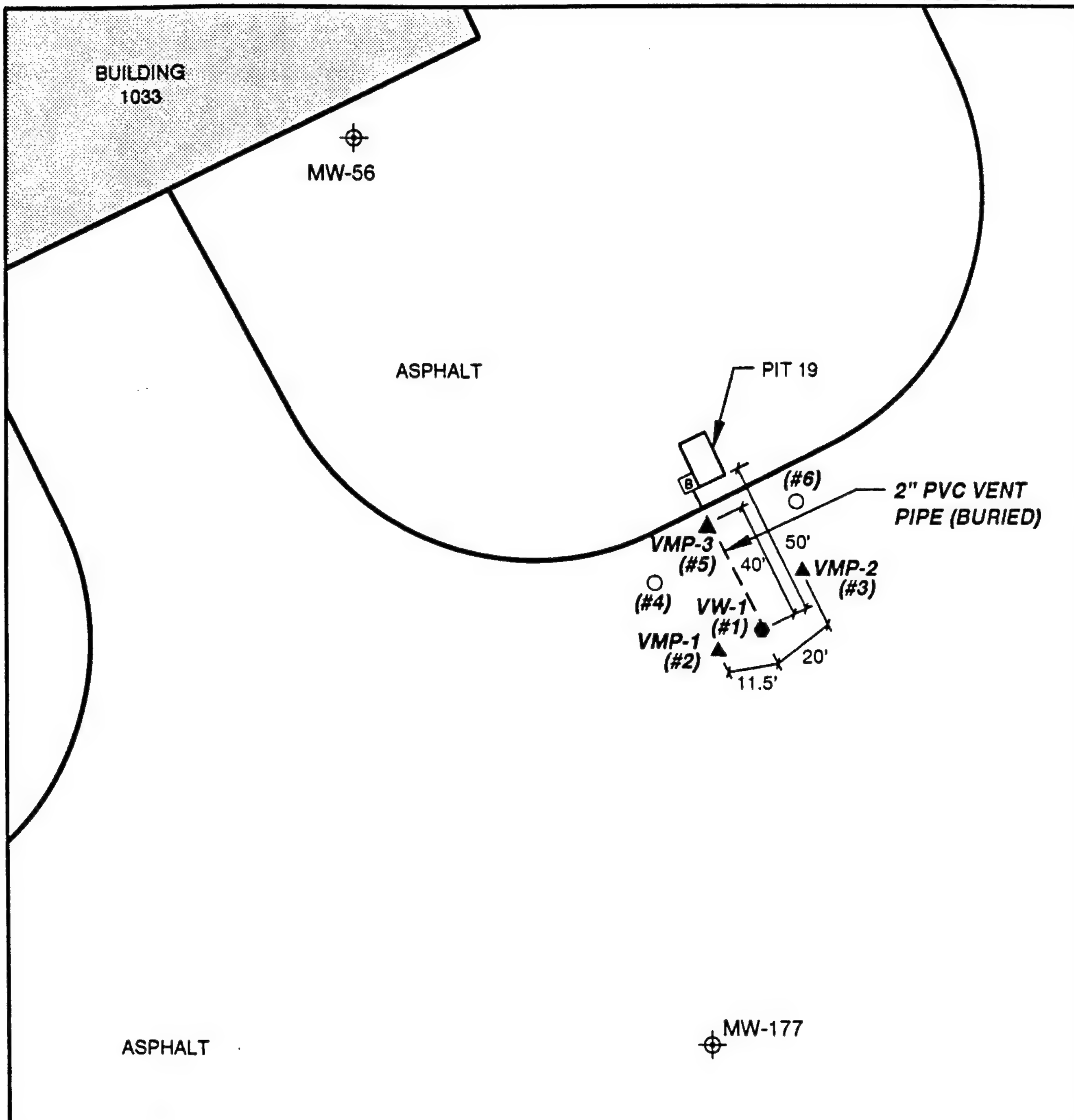
EXPLANATION

PI 1	PRESSURE INDICATOR
TI 1	TEMPERATURE INDICATOR
VI 1	VACUUM INDICATOR
ABV	AIR BLEED VALVE
PRV	PRESSURE RELIEF VALVE
FCV	FLOW CONTROL VALVE

AS-BUILT BLOWER PROCESS FLOW AND INSTRUMENTATION DIAGRAM (TYPICAL)

FAIRCHILD AIR FORCE BASE, WASHINGTON

FIGURE 1.4



EXPLANATION

MW-177	GROUNDWATER MONITORING WELL
(#4)	ABANDONED BOREHOLE
B	BLOWER LOCATION
VW-1 (#1)	VENT WELL (AND SOIL BORING NUMBER)
VMP-1 (#2)	VAPOR MONITORING POINT (AND SOIL BORING NUMBER)

SOURCE: MODIFIED FROM HALLIBURTON NUS (1993)

N

0 25 50
SCALE IN FEET

AS-BUILT VENT WELL AND VAPOR MONITORING POINT LOCATIONS PS-2

FAIRCHILD AIR FORCE BASE, WASHINGTON

REV. 4 CC341-04.DWG 06/09/94

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abandoned because a large void/cavity of unknown origin was encountered at 6.5 feet bgs. Table 1.1 summarizes pertinent data for the boreholes converted to VMPs and the VW.

1.4.2 Soil Profile

Figure 1.5 is a geologic cross-section of the pilot test site using data from the VW and the three VMPs. The interpreted soil profile is shown along with OVA readings, VW and VMP screened intervals, TRPH concentrations from laboratory analysis of soil samples, and initial oxygen levels in soil gas. The soil boring logs are included in Appendix A.

Below the surface asphalt, the observed soil profile from the surface down to about 1.5 to 2 feet below ground surface (bgs) is a gray to grayish-green predominantly gravelly sand material. This material exhibited a noticeable fuel odor in all boreholes. A lens of dark greenish-gray sand lies from 2 to 2.5 feet bgs in VW-1. Below 1.5 to 2.5 feet bgs lies a dark brown to greenish-gray predominantly silty sand with minor gravel, however, a lens of clean sand extends from approximately 5 to 5.5 feet bgs in VMP-3. The silty sand extends to the bottom of the borehole in VMP-2 and VMP-3 and to 8 feet bgs in VW-1 and VMP-1. This silty sand exhibited a fuel odor in all boreholes. Beneath the silty sand, to a depth of 9 feet bgs in VMP-1 and to the base of the borehole in VW-1, lies a dark brown clay which exhibited noticeable fuel odor.

Groundwater was encountered at a depth of 9 feet bgs in VW-1 as shown on Figure 1.5.

1.4.3 Air Injection Vent Well

One air injection VW (VW-1) was installed following procedures described in Section 1.1. VW-1 was installed approximately 50 feet southeast of Pit 19 (Figure 1.4). The screen was set between 5 and 10 feet bgs. Site-specific construction details for the VW installed at PS-2 are contained in Table 1.2 and Figure 1.1.

The surface completion of the VW consisted of a heavy-duty, 16-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 2.5-foot diameter concrete collar. As part of required flightline construction specifications, the cast-iron well-box was placed on top of a 3-foot square, steel reinforced concrete pad underlain by pea gravel.

VW-1 was connected to the blower unit by 2-inch diameter Schedule 40 PVC pipe buried in a trench. The trench, approximately 50 feet long, 8 inches wide, and 1 foot deep, was excavated from the blower location to VW-1. Surface asphalt was cut away and removed prior to trenching work. A bed of pea gravel was poured in the bottom of the trench and then the PVC pipe was placed in the trench.

After securing the pipe, soil was returned to the trench and compacted. Asphalt was then replaced over the trenched area. The horizontal pipe was elbowed below ground at the designated blower location and the top of the vertical PVC pipe was cut to approximately two feet above ground surface. The above ground PVC pipe was connected directly to the portable blower unit for the initial pilot test and then to the fixed blower unit for the extended pilot test.

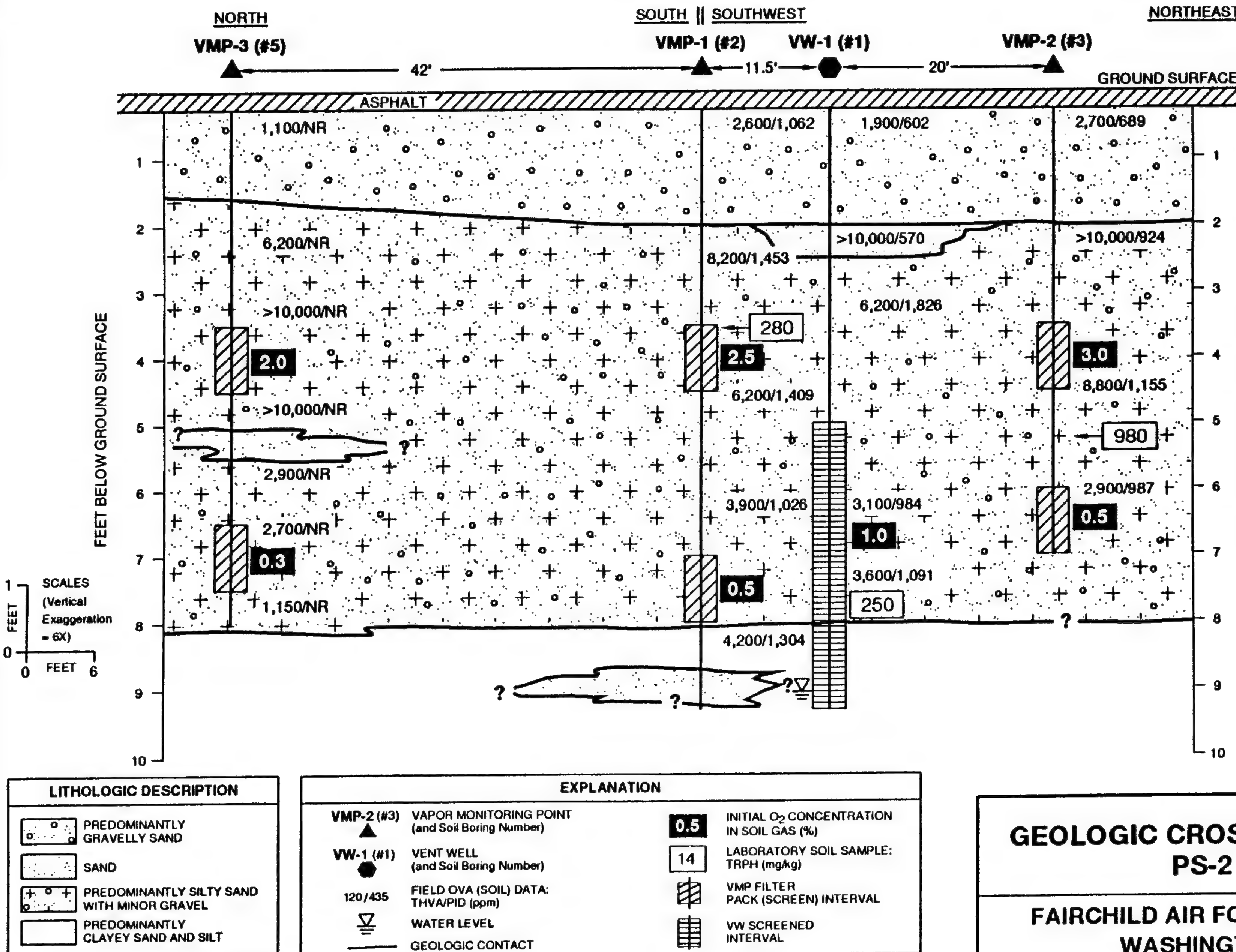
TABLE 1.1
BOREHOLE, SOIL SAMPLE, AND VMP/VW SUMMARY DATA
PS-2
Fairchild AFB, Washington

BOREHOLE ID #	BOREHOLE TOTAL DEPTH (ft. bgs)	SOIL SAMPLE INTERVAL (ft. bgs)	THVA/PID HEADSPACE READINGS (PPM)	SOIL SAMPLE ID #	START DATE	COMPLETION DATE	COMPLETION DESIGNATION
1	9	0-0.5	1,900/602		9/22/93	9/25/93	VW-1
		2.0-2.5	>10,000/570				
		3.0-3.5	6,200/1,826				
		6.0-6.5	3,100/984				
		7.0-7.5	3,600/1,091				
		7.5-8.5	NR/NR	PS2-VW1-7.5			
2	9	0-0.5	2,600/1,062		9/23/93	9/25/93	VMP-1
		2.0-2.5	8,200/1,453				
		3.5-4.0	NR/NR	PS2-VMP1-4			
		4.0-4.5	6,200/1,409				
		6.0-6.5	3,900/1,026				
		8.0-8.5	4,200/1,304				
3	7.2	0-0.5	2,700/689		9/24/93	9/26/93	VMP-2
		2.0-2.5	>10,000/924				
		4.0-4.5	8,800/1,155				
		4.5-6.0	NR/NR	PS2-VMP2-4			
		6.0-6.5	2,900/987				
5	8	0-0.5	1,100/NR		9/28/93	9/28/93	VMP-3
		2.0-2.5	6,200/NR				
		3.0-3.5	>10,000/NR				
		4.5-5.0	>10,000/NR				
		5.5-6.0	2,900/NR				
		6.5-7.0	2,700/NR				
		7.5-8.0	1,150/NR				

NR - Not Recorded

06/09/94
ps2.xls

FIGURE 1.5



GEOLOGIC CROSS-SECTION PS-2

FAIRCHILD AIR FORCE BASE, WASHINGTON

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TABLE 1.2
VMP/VW CONSTRUCTION DATA
PS-2
Fairchild AFB, Washington

WELL ID #	BOREHOLE TOTAL DEPTH (ft.bgs)	VW SCREEN INTERVAL (ft.bgs)	CENTER of VMP SCREEN (ft.bgs)	FILTER PACK INTERVAL(s) (ft.bgs)	BENTONITE INTERVAL(s) (ft.bgs)	GROUT INTERVAL(s) (ft.bgs)
VW-1	9	5.0 - 10.0	-	4.5 - 10.0	2.5 - 4.5	2.0 - 2.5
VMP-1	9	-	4.0	3.5 - 4.5	2.0 - 3.5	1.5 - 2.0
			7.5	7.0 - 8.0	4.5 - 7.0	
					8.0 - 9.0	
VMP-2	7.2	-	4.0	3.5 - 4.5	2.0 - 3.5	1.5 - 2.0
			6.5	6.0 - 7.0	4.5 - 6.0	
					7.0 - 7.2	
VMP-3	8	-	4.0	3.5 -4.5	2.0 - 3.5	1.5 - 2.0
			7.0	6.5 - 7.5	4.5 - 6.5	
					7.5 - 8.0	

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ps2.xls

1.4.4 Vapor Monitoring Points

VMP-1, VMP-2, and VMP-3 were installed at distances from VW-1 of 11.5 feet, 20 feet, and 40 feet, respectively (Figure 1.4). Each VMP was located in a different direction from the VW in an attempt to place VMPs near previously drilled borings in which contamination was identified during prior investigations (see Part I, Section 2.1).

All VMPs were installed following procedures described in the protocol document and as detailed in Section 1.2. Site-specific construction details for the VMPs installed at PS-2 are contained in Table 1.2 and Figure 1.2. All three VMPs have nearly identical construction details with only slight variations in actual screened intervals. The center of the screened intervals for each VMP are located as follows: 4 and 7.5 feet bgs for VMP-1; 4 and 6.5 feet bgs for VMP-2; and 4 and 7 feet bgs for VMP-3.

The surface completion of the VMPs consisted of a heavy-duty, 12-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 2.5-foot diameter concrete collar. A steel-reinforced concrete pad was not used for the VMP surface completion due to their small diameter.

1.4.5 Blower Unit

The fixed regenerative blower unit was installed on 7 October 1993 and began operation on 9 March 1994 for the extended pilot test at PS-2. At the time of installation, the fixed blower unit was injecting approximately 27 scfm. The unit is powered by a line installed by an electrical subcontractor which runs to Pit 19 from Building 1033 (see Figure 1.4).

1.4.6 Exceptions to Protocol Document Procedures

Protocol document procedures related to pilot test design and construction were followed with no significant exceptions.

1.5 PS-1A

1.5.1 Introduction

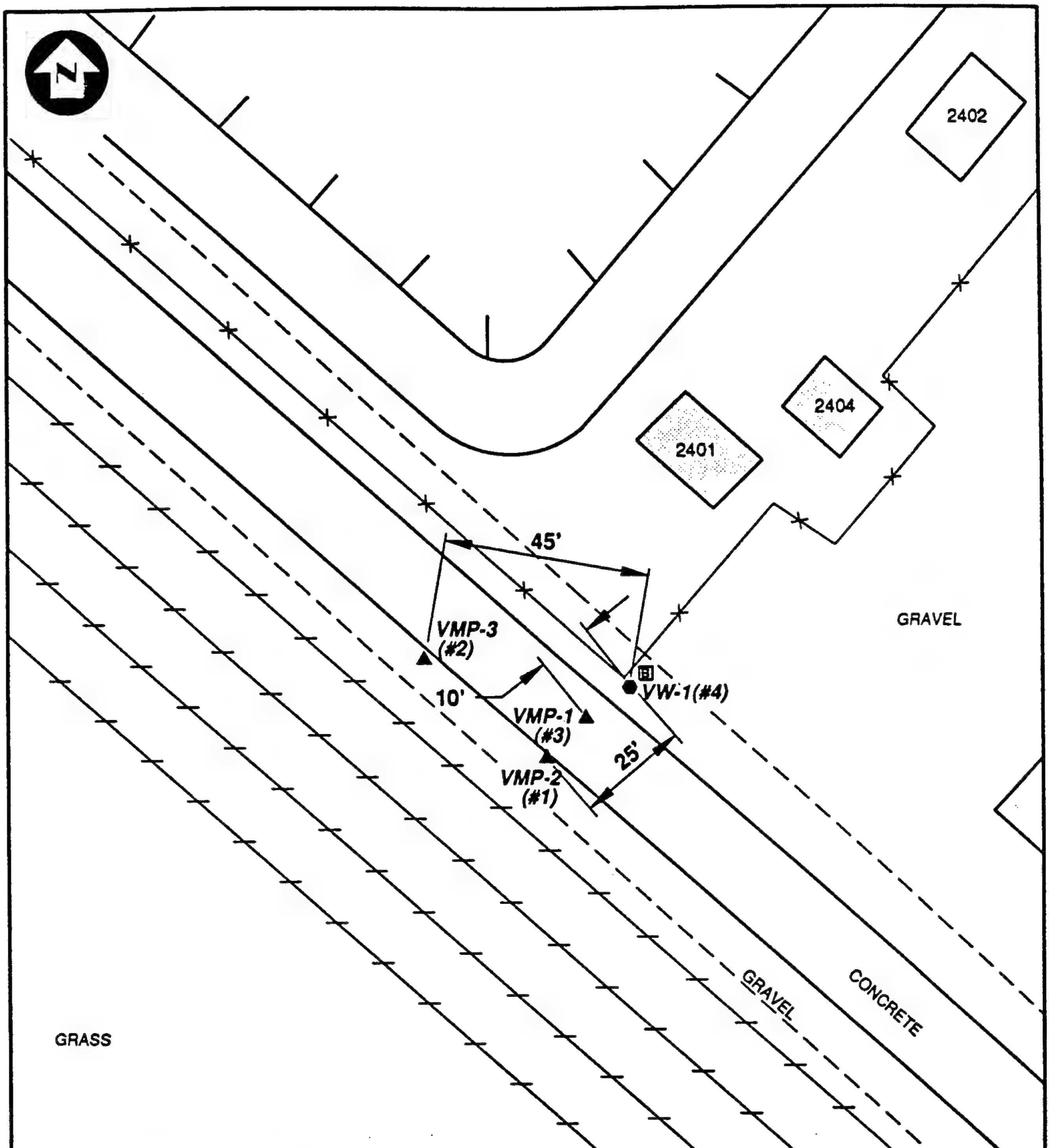
Installation of one VW (VW-1) and three VMPs (VMP-1, VMP-2, and VMP-3) was conducted at PS-1A between 13 and 18 October 1993. Locations of the VWs and VMPs are shown on Figure 1.6. Four boreholes were drilled at the site and all were converted to either a VW or a VMP. Table 1.3 summarizes pertinent borehole data.

1.5.2 Soil Profile

Figure 1.7 is a geologic cross-section of the pilot test site using data from the VW and the three VMPs. The interpreted soil profile is shown along with OVA readings, VW and VMP screened intervals, TRPH concentrations from laboratory analysis of soil samples, and initial oxygen levels in soil gas. The soil boring logs are included in Appendix A.

The observed soil profile in VW-1, VMP-2 and VMP-3 from surface to a depth of 1.5 to 2 feet bgs is a dark brown silty sand with occasional gravel and/or clay. Below this layer in VW-1 and VMP-2 and below the surface concrete in VMP-1 is a predominantly dark-brown silty sand; in these boreholes, this silty sand occurs to a depth of 3.5 to 4.5

FIGURE 1.6



EXPLANATION

- BLOWER LOCATION
- VW-1 (#4) VENT WELL (AND SOIL BORING NUMBER)
- VMP-1 (#3) VAPOR MONITORING POINT (AND SOIL BORING NUMBER)
- FUEL LINES
- FENCE
- RAILROAD TRACKS

SOURCE: MODIFIED FROM ICF (1993b)

0 15 30

SCALE IN FEET

AS BUILT VENT WELL AND VAPOR MONITORING POINT LOCATIONS PS-1A

FAIRCHILD AIR FORCE BASE, WASHINGTON

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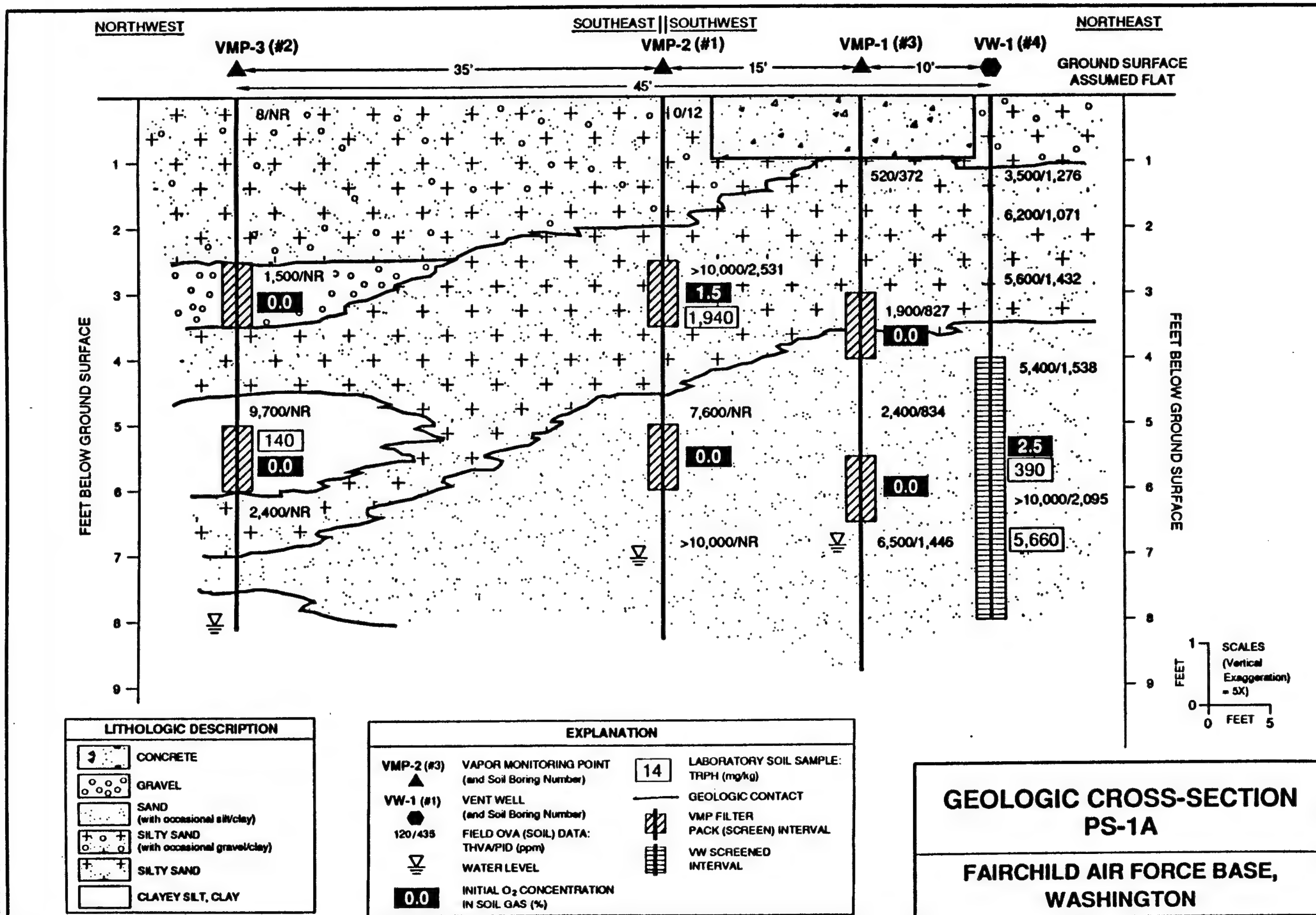
TABLE 1.3
BOREHOLE, SOIL SAMPLE, AND VMP/VW SUMMARY DATA
PS-1A
Fairchild AFB, Washington

BOREHOLE ID #	BOREHOLE TOTAL DEPTH (ft. bgs)	SOIL SAMPLE INTERVAL (ft. bgs)	THVA/PID HEADSPACE READINGS (ppmv)	SOIL SAMPLE ID #	START DATE	COMPLETION DATE	COMPLETION DESIGNATION
1	8	0.5-1.0	0/12		10/13/93	10/18/93	VMP-2
		2.5-3.0	>10,000/2,531				
		3.0-4.0	NR/NR	PS1A-VMP2-4			
		4.5-5.0	7,600/NR				
		6.5-7.0	>10,000/NR				
2	8	1.2-1.7	8/NR		10/13/93	10/14/93	VMP-3
		3.2-3.7	1,500/NR				
		5.2-5.7	9,700/NR				
		5.7-6.7	NR/NR	PS1A-VMP3-6			
		6.7-7.2	2,400/NR				
3	8	0.5-1.0	520/372		10/14/93	10/14/93	VMP-1
		2.5-3.0	1,900/827				
		4.0-4.5	2,400/834				
		6.0-6.5	6,500/1,446				
4	8	1.0-1.5	3,500/1,276		10/18/93	10/18/93	VW-1
		1.5-2.0	6,200/1,071				
		2.5-3.0	5,600/1,432				
		4.0-4.5	5,400/1,530				
		4.5-6.0	NR/NR	PS1A-VW1-6			
		6.0-6.5	>10,000/2,095				
		6.5-7.0	NR/NR	PS1A-VMP4-7			

NR = Not Recorded

06/09/94

ps1a.xls



GEOLOGIC CROSS-SECTION PS-1A

FAIRCHILD AIR FORCE BASE, WASHINGTON

FIGURE 1.7

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feet bgs. The dark brown silty sand also occurs in VMP-3 in the intervals from 3.5 to 4.5 feet bgs and 6 to 7 feet bgs. This material exhibited a noticeable fuel odor in VMP-2. An olive gray to greenish-gray sand underlies the silty sand. This interval exhibited a noticeable fuel odor in VW-1, VMP-1 and VMP-2.

The soil profile for VMP-3 contains several additional layers: from 2.5 to 3.5 feet bgs is a gray gravel, from 4.5 to 6 feet bgs is a brownish black clayey silty which exhibited noticeable fuel odors, and from 7.5 to the base of the borehole is a brown clay.

Groundwater was encountered in VMP-1, VMP-2 and VMP-3; groundwater levels are shown on Figure 1.7. Initial encountered levels were: approximately 7 feet bgs in VMP-1 and VMP-2 and 8 feet bgs in VMP-3.

1.5.3 Air Injection Vent Well

One air injection VW (VW-1) was installed following procedures described in Section 1.1. VW-1 was installed adjacent to the south corner of the perimeter fence (Figure 1.6). The screen was set between 4 and 8 feet bgs. Site-specific construction details for the VW installed at PS-1A are contained in Table 1.4 and Figure 1.1.

The surface completion of the VW consisted of an 18-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 3-foot diameter concrete collar.

VW-1 was connected to the blower unit by 2-inch diameter Schedule 40 PVC pipe buried in a trench. The trench, approximately 4 feet long, 8 inches wide, and 1 foot deep, was excavated from the blower location to VW-1. After securing the pipe, soil was returned to the trench and compacted.

The horizontal pipe was elbowed below ground at the designated blower location and the top of the vertical PVC pipe was cut to approximately two feet above ground surface. The above ground PVC pipe was connected directly to the portable blower unit for the initial pilot test and then to the fixed blower unit for the extended pilot test.

1.5.4 Vapor Monitoring Points

VMP-1, VMP-2, and VMP-3 were installed at distances from VW-1 of 10 feet, 25 feet, and 45 feet, respectively (Figure 1.6). VMP-1 was located in the roadway where prior investigations had found soil contamination and the remaining two VMPs were located on the opposite side of the roadway, where a previous soil-gas survey had shown contamination in soil gas (see Part I, Section 2.2).

All VMPs were installed following procedures described in the protocol document and as detailed in Section 1.2. Site-specific construction details for the VMPs installed at PS-1A are contained in Table 1.4 and Figure 1.2. All three VMPs have nearly identical construction details with only slight variations in actual screened intervals. The center of the screened intervals for each VMP are located as follows: 3.7 and 6.2 feet bgs for VMP-1; 3 and 5.5 feet bgs for VMP-2; and 3 and 5.5 feet bgs for VMP-3.

TABLE 1.4
VMP/VW CONSTRUCTION DATA
PS-1A
Fairchild AFB, Washington

WELL ID #	BOREHOLE TOTAL DEPTH (ft.bgs)	VW SCREEN INTERVAL (ft.bgs)	CENTER of VMP SCREEN (ft.bgs)	FILTER PACK INTERVAL(s) (ft.bgs)	BENTONITE INTERVAL(s) (ft.bgs)	GROUT INTERVAL(s) (ft.bgs)
VW-1	8	4.0-8.0	-	3.75-8.0	2.0-3.75	1.5-2.0
VMP-1	8.8	-	3.7	3.2-4.2	2.2-3.2	1.7-2.2
			6.2	5.7-6.7	4.2-5.7	
					6.7-8.7	
VMP-2	8	-	3.0	2.5-3.5	2.0-2.5	1.5-2.0
			5.5	5.0-6.0	3.5-5.0	
					6.0-8.0	
VMP-3	8	-	3.0	2.5-3.5	2.0-2.5	1.5-2.0
			5.5	5.0-6.0	3.5-5.0	
					6.0-8.0	

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ps1a.xls

The surface completion of the VMPs consisted of a 12-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 2.5-foot diameter concrete collar.

1.5.5 Blower Unit

The fixed regenerative blower unit was installed on 29 October 1993 and began operation on 3 March 1994 for the extended pilot test at PS-1A. At the time of installation, the fixed blower unit was injecting approximately 34 scfm. The unit is powered by a line installed by an electrical subcontractor which runs to the blower along the fence and originating from Building 2402 (see Figure 1.6).

1.5.6 Exceptions to Protocol Document Procedures

Protocol document procedures related to pilot test design and construction were followed with no significant exceptions.

1.6 PS-1B

1.6.1 Introduction

Installation of one VW (VW-1) and three VMPs (VMP-1, VMP-2, and VMP-3) was conducted at PS-1B between 20 and 22 October 1993. Locations of the VWs and VMPs are shown on Figure 1.8. Four boreholes were drilled at the site and all were converted to either a VW or a VMP. Table 1.5 summarizes pertinent borehole data.

1.6.2 Soil Profile

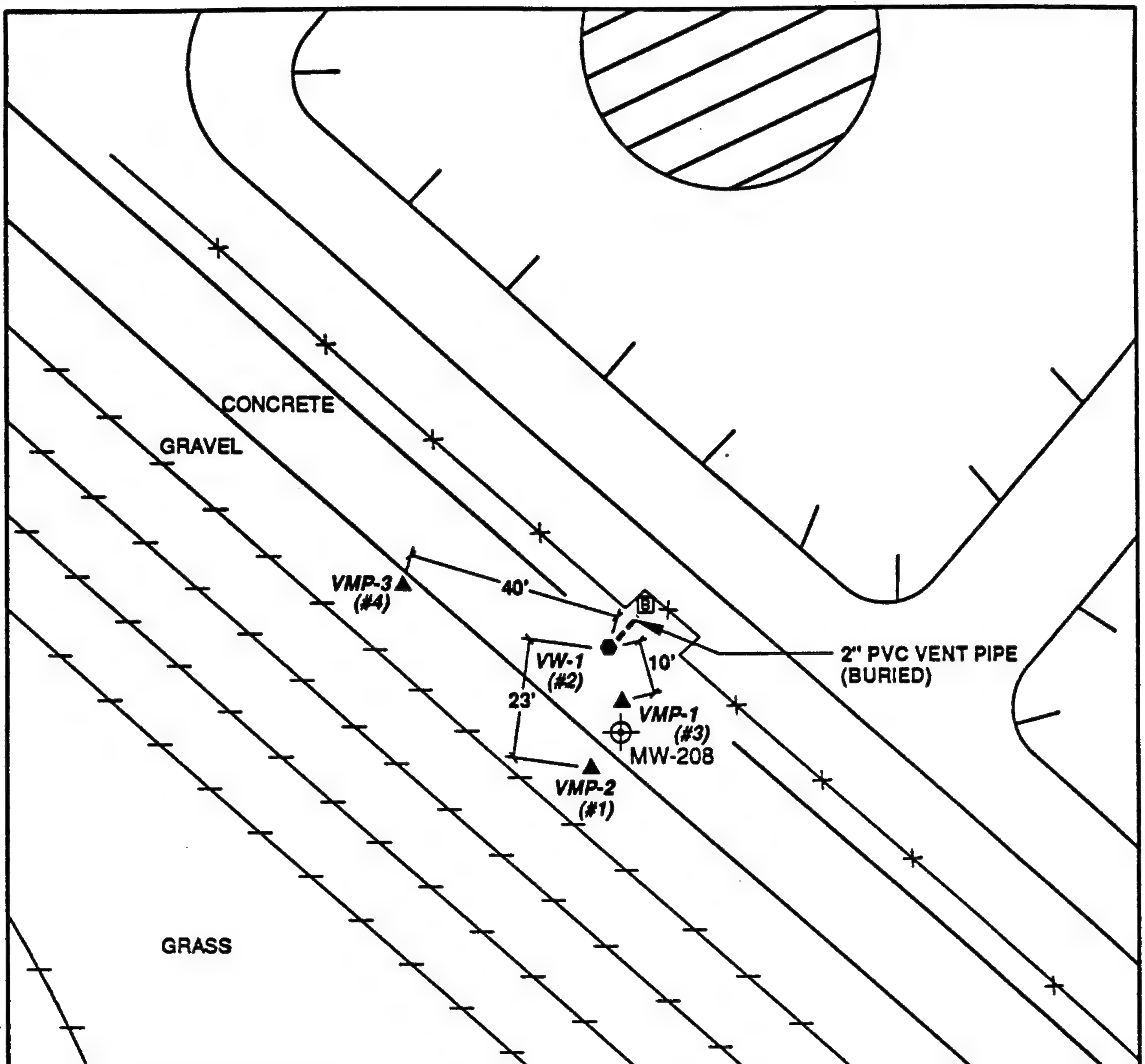
Figure 1.9 is a geologic cross-section of the pilot test site using data from the VW and the three VMPs. The interpreted soil profile is shown along with OVA readings, VW and VMP screened intervals, TRPH concentrations from laboratory analysis of soil samples, and initial oxygen levels in soil gas. The soil boring logs are included in Appendix A.

Approximately 8 inches of concrete overlies the soils in VW-1 and VMP-1. A dark brown silty sand and gravel layer exists from surface to 1 foot bgs in VMP-2. A predominantly dark-brown silty sand with occasional gravel and/or clay lies below the surface in VMP-3, and beneath the concrete in VW-1 and VMP-1, and beneath the silty sand and gravel in VMP-2. This silty sand extends to a depth of approximately 4 to 6 feet bgs; however, an additional layer of dark brown silty sand and gravel exists in VW-1 from 1 to 2 feet bgs. The extensive silty sand interval exhibited a noticeable fuel odor in VMP-1, VMP-2 and VMP-3.

Below the silty sand is a gray to dark gray sand which exhibited a noticeable fuel odor in all boreholes. A gray clay begins at approximately 7.5 to 8.5 feet bgs in VW-1, VMP-1, and VMP-3 and continues to the base of these boreholes. This clay exhibited noticeable fuel odor in VW-1 and VMP-3.

Groundwater was not encountered in any of the borings at the site.

FIGURE 1.8



EXPLANATION

MW-208 — GROUNDWATER MONITORING WELL

BLOWER LOCATION

VW-1 (#2) — VENT WELL (AND SOIL BORING NUMBER)

VMP-2 (#1) — VAPOR MONITORING POINT (AND SOIL BORING NUMBER)

ABOVE GROUND STORAGE TANK

RAILROAD TRACK

FENCE

0 15 30
SCALE IN FEET

AS-BUILT VENT WELL AND MONITORING POINT LOCATIONS PS-1B

FAIRCHILD AIR FORCE BASE, WASHINGTON

REV. 0 C274-06.DWG 02/03/94

ENGINEERING-SCIENCE, INC.

TABLE 1.5
'BOREHOLE, SOIL SAMPLE, AND VMP/VW SUMMARY DATA
PS-1B
Fairchild AFB, Washington

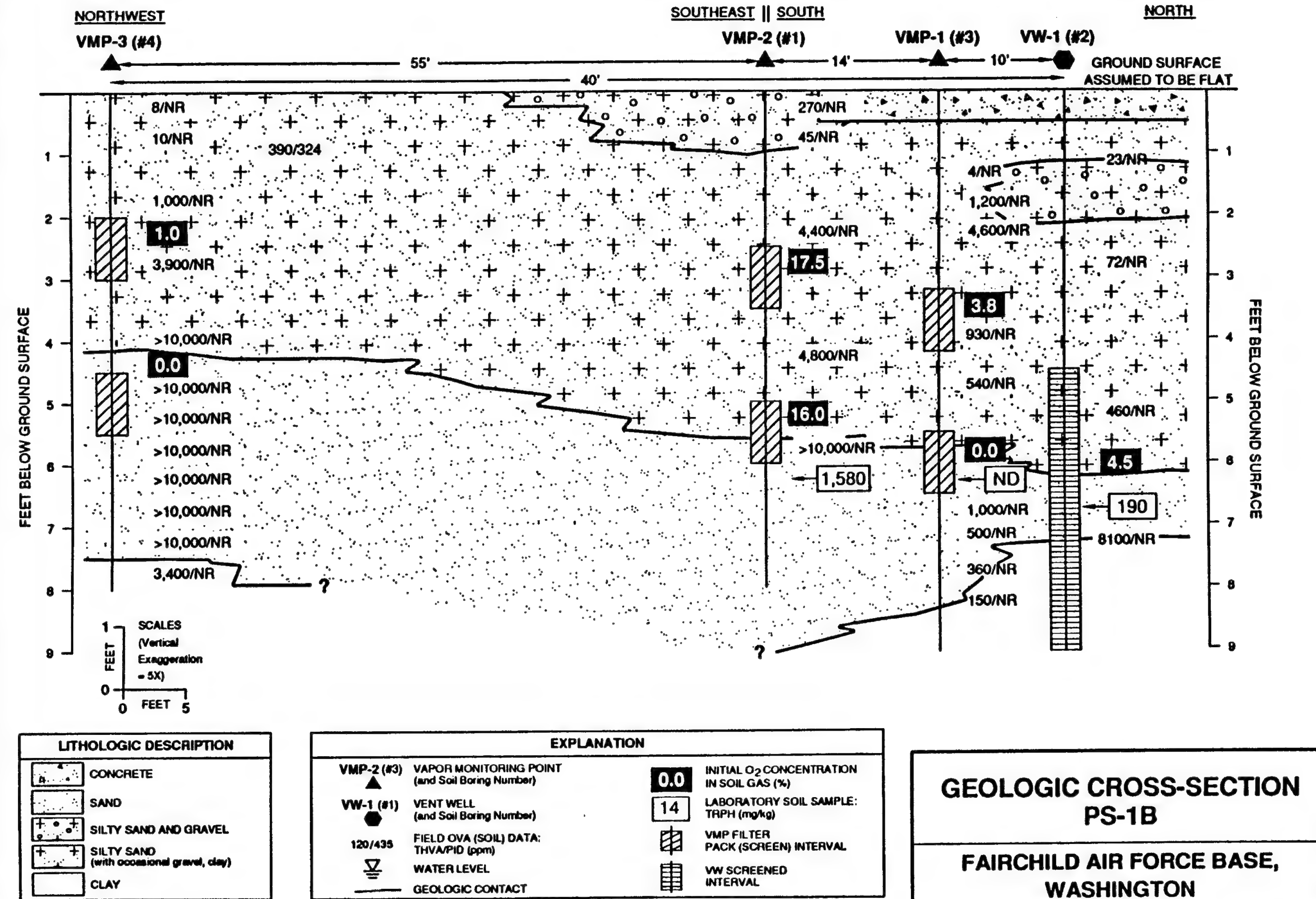
BOREHOLE ID #	BOREHOLE TOTAL DEPTH (ft. bgs)	SOIL SAMPLE INTERVAL (ft. bgs)	THVA/PID HEADSPACE READINGS (ppmv)	SOIL SAMPLE ID #	START DATE	COMPLETION DATE	COMPLETION DESIGNATION
1	8	0-0.5	270/NR		10/20/93	10/20/93	VMP-2
		0.5-1.0	45/NR				
		2.0-2.5	4,400/NR				
		4.0-4.5	4,800/NR				
		6.0-6.5	>10,000/NR				
		6.5-7.0	NR/NR	PS1B-VMP2-6			
2	8.8	1.2-1.7	23/NR		10/20/93	10/20/93	VW-1
		2.7-3.2	72/NR				
		5.2-5.7	460/NR				
		6.7-7.2	NR/NR	PS1B-VW1-6			
		6.5-7.0	8,100/NR				
3	8.8	1.2-1.7	4/NR		10/21/93	10/21/93	VMP-1
		1.7-2.2	1,200/NR				
		2.2-2.7	4,600/NR				
		3.2-3.7	930/NR				
		4.7-5.2	540/NR				
		5.2-6.7	NR/NR	PS1B-VMP1-5.5			
		6.7-7.2	1,000/NR				
		7.2-7.7	500/NR				
		7.7-9.2	360/NR				
		9.2-9.7	150/NR				
4	8	0-0.5	8/NR		10/22/93	10/22/93	VMP-3
		0.5-1.0	10/NR				
		1.5-2.0	1,000/NR				
		2.5-3.0	3,900/NR				
		3.5-4.0	>10,000/NR				
		4.5-5.0	>10,000/NR				
		5.0-5.5	>10,000/NR				
		5.5-6.0	>10,000/NR				
		6.0-6.5	>10,000/NR				
		6.5-7.0	>10,000/NR				
		7.0-7.5	>10,000/NR				
		7.5-8.0	3,400/NR				

NR = Not Recorded

6/9/94

ps1b.xls

FIGURE 1.9



GEOLOGIC CROSS-SECTION PS-1B

FAIRCHILD AIR FORCE BASE, WASHINGTON

REV. 3 C274-05.DWG 05/20/94

ENGINEERING-SCIENCE, INC.

1.6.3 Air Injection Vent Well

One air injection VW (VW-1) was installed following procedures described in Section 1.1. VW-1 was installed at the edge of the roadway, just opposite the "notch" in the fenceline (Figure 1.8). The screen was set between 4.5 and 8.8 feet bgs. Site-specific construction details for the VW installed at PS-1B are contained in Table 1.6 and Figure 1.1.

The surface completion of the VW consisted of an 18-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 3-foot diameter concrete collar.

VW-1 was connected to the blower unit by 2-inch diameter Schedule 40 PVC pipe buried in a trench. The trench, approximately 8 feet long, 8 inches wide, and 1 foot deep, was excavated from the blower location to VW-1. Surface concrete between the VW-1 and the curb was cut away and removed prior to trenching work. After securing the pipe, soil was returned to the trench and compacted. The roadway was then patched with replacement concrete.

The horizontal pipe was elbowed below ground at the designated blower location and the top of the vertical PVC pipe was cut to approximately two feet above ground surface. The above ground PVC pipe was connected directly to the portable blower unit for the initial pilot test and then to the fixed blower unit for the extended pilot test.

1.6.4 Vapor Monitoring Points

VMP-1, VMP-2, and VMP-3 were installed at distances from VW-1 of 10 feet, 23 feet, and 40 feet, respectively (Figure 1.8). VMP-1 was located in the roadway next to groundwater monitoring well MW-208, where prior investigations had found soil contamination, and the remaining two VMPs were located on the opposite side of the roadway, where a previous soil-gas survey had shown contamination in soil gas (see Part I, Section 2.2).

All VMPs were installed following procedures described in the protocol document and as detailed in Section 1.2. Site-specific construction details for the VMPs installed at PS-1B are contained in Table 1.6 and Figure 1.2. All three VMPs have nearly identical construction details with only slight variations in actual screened intervals. The center of the screened intervals for each VMP are located as follows: 3.3 and 5.8 feet bgs for VMP-1; 3 and 5.5 feet bgs for VMP-2; and 2.5 and 5 feet bgs for VMP-3.

The surface completion of the VMPs consisted of a 12-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 2.5-foot diameter concrete collar.

1.6.5 Blower Unit

The fixed regenerative blower unit was installed on 5 November 1993 and began operation on 3 March 1994 for the extended pilot test at PS-1B. At the time of installation, the fixed blower unit was injecting approximately 23 scfm. The unit is

TABLE 1.6
VMP/VW CONSTRUCTION DATA
PS-1B
Fairchild AFB, Washington

WELL ID #	BOREHOLE TOTAL DEPTH (ft.bgs)	VW SCREEN INTERVAL (ft.bgs)	CENTER of VMP SCREEN (ft.bgs)	FILTER PACK INTERVAL(s) (ft.bgs)	BENTONITE INTERVAL(s) (ft.bgs)	GROUT INTERVAL(s) (ft.bgs)
VW-1	8.8	4.5-8.8	-	4.3-8.8	2.3-4.3	1.8-2.3
VMP-1	8.8	-	3.3	2.8-3.8	1.8-2.8	1.3-1.8
			5.8	5.3-6.3	3.8-5.3	
					6.3-8.8	
VMP-2	8	-	3.0	2.5-3.5	1.5-2.5	None
			5.5	5.0-6.0	3.5-5.0	
					6.0-8.0	
VMP-3	8	-	2.5	2.0-3.0	-	1.5-2.0
			5.0	4.5-5.5	3.0-4.5	
					5.5-8.0	

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ps1b.xls

powered by a line installed by an electrical subcontractor which runs to the blower along the fence and originating from Building 2402 (see Figure 1.6 and Figure 1.8).

1.6.6 Exceptions to Protocol Document Procedures

Protocol document procedures related to pilot test design and construction were followed with no significant exceptions.

1.7 Building 2034

1.7.1 Introduction

Installation of one VW (VW-1) and three VMPs (VMP-1, VMP-2, and VMP-3) was conducted at Building 2034 between 30 September and 4 October 1993. Locations of the VWs and VMPs are shown on Figure 1.10. Five boreholes were drilled at the site and four were converted to either a VW or a VMP. One borehole was abandoned. Table 1.7 summarizes pertinent borehole data.

1.7.2 Soil Profile

Figure 1.11 is a geologic cross-section of the pilot test site using data from the VW and the three VMPs. The interpreted soil profile is shown along with OVA readings, VW and VMP screened intervals, TRPH concentrations from laboratory analysis of soil samples, and initial oxygen levels in soil gas. The soil boring logs are included in Appendix A.

The observed soil profile in VW-1, VMP-1 and VMP-2 from surface to 0.5 to 1 foot bgs is a brown to dark brown sand and gravel. Beneath this layer and below ground surface in VMP-3 lies a brown to brownish-black silty sand with occasional gravel and/or clay. This silty sand extends to a depth of 8.5 to 9.5 feet bgs. This interval exhibits a noticeable fuel odor in VW-1, VMP-1 and VMP-2.

In VMP-1 and VMP-2, a dark brown to greenish brown-black sand layer underlies the silty sand. The sand continues to the bottom of the borehole in VMP-1 and to 9.5 feet bgs in VMP-2. A light brown to brown clay occurs at the bottom of the soil profile in VW-1, VMP-2 and VMP-3. This clay interval exhibits a noticeable fuel odor in VMP-3.

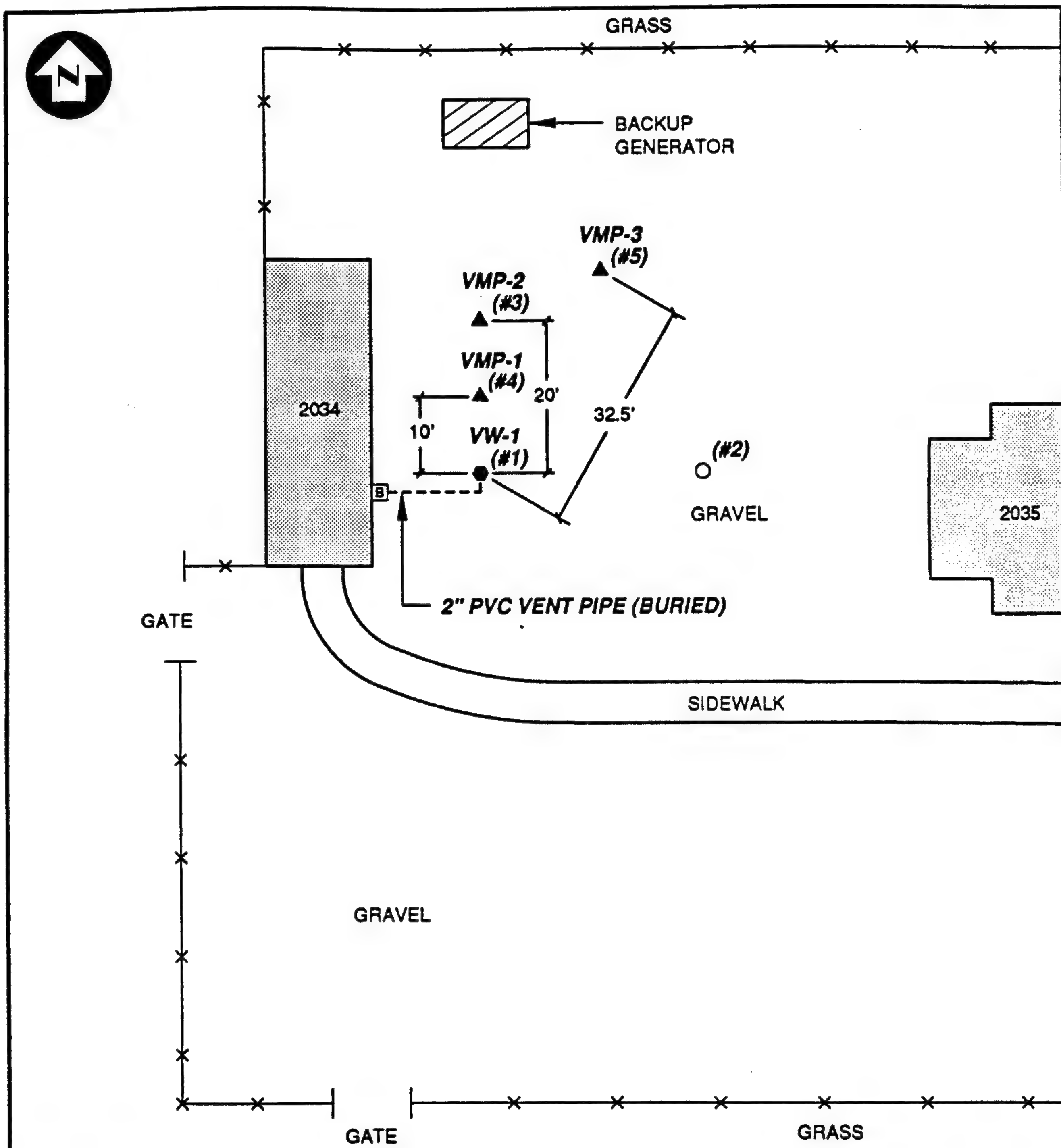
Groundwater was encountered at a depth of 10 feet bgs in VW-1 as shown on Figure 1.11.

1.7.3 Air Injection Vent Well

One air injection VW (VW-1) was installed following procedures described in Section 1.1. VW-1 was installed approximately 15 feet east of Building 2034 (Figure 1.10). The screen was set between 5 and 10 feet bgs. Site-specific construction details for the VW installed at Building 2034 are contained in Table 1.8 and Figure 1.1.

The surface completion of the VW consisted of an 18-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 3-foot diameter concrete collar.

FIGURE 1.10



EXPLANATION

FENCE

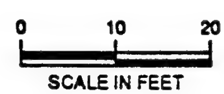
B BLOWER LOCATION

(#2) ABANDONED BOREHOLE

VMP-1 (#2) VAPOR MONITORING POINT (AND SOIL BORING NUMBER)

VW-1 (#1) VENT WELL (AND SOIL BORING NUMBER)

SOURCE: FAIRCHILD AFB (1993)



AS-BUILT VENT WELL AND MONITORING POINT LOCATIONS BUILDING 2034

FAIRCHILD AIR FORCE BASE, WASHINGTON

REV. 1 C274-02.DWG 05/20/94

ENGINEERING-SCIENCE, INC.

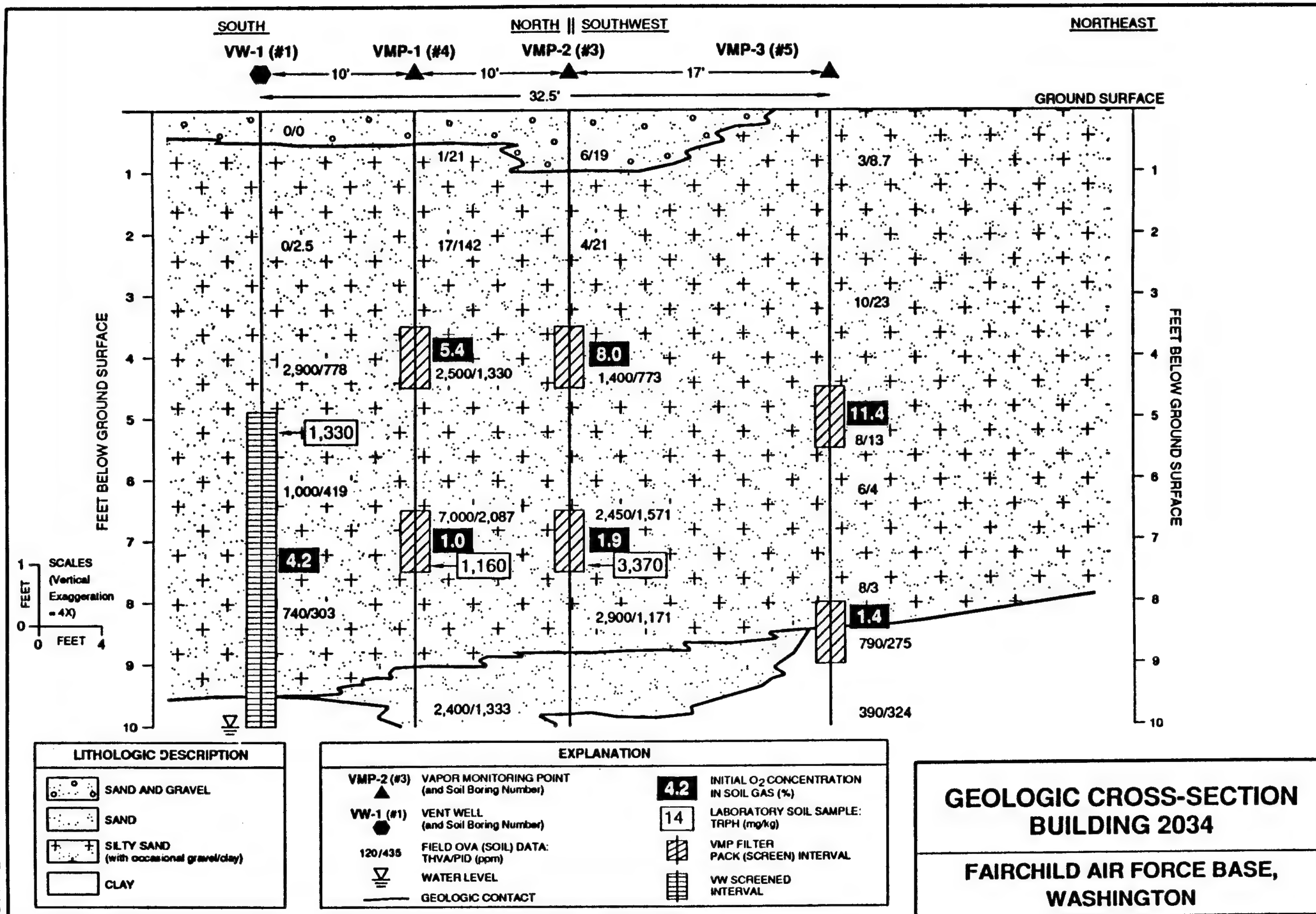
TABLE 1.7
BOREHOLE, SOIL SAMPLE, AND VMP/VW SUMMARY DATA
Building 2034
Fairchild AFB, Washington

BOREHOLE ID #	BOREHOLE TOTAL DEPTH (ft. bgs)	SOIL SAMPLE INTERVAL (ft. bgs)	THVA/PID HEADSPACE READINGS (ppmv)	SOIL SAMPLE ID #	START DATE	COMPLETION DATE	COMPLETION DESIGNATION
1	10	0.0 - 0.5	0/0		9/30/93	10/1/93	VW-1
		2.5 - 3.0	0.0/2.5				
		4.0 - 4.5	2,900/778				
		4.5 - 6.0	NR/NR	B2034-VW1-5			
		6.5 - 7.0	1,000/419				
		8.0 - 8.5	740/303				
2	10	0.5 - 1.0	2.0/3.0		9/30/93	10/3/93	Abandoned
		2.0 - 2.5	4.0/3.0				
		4.0 - 4.5	880/330				
		6.5 - 7.0	800/188				
		8.0 - 8.5	220/118				
3	10	0.5 - 1.0	6/19		9/30/93	10/1/93	VMP-2
		2.5 - 3.0	4/21				
		4.0 - 4.5	1,400/773				
		6.0 - 6.5	2450/1571				
		6.5 - 8.0	NR/NR	B2034-VMP2-7			
		8.0 - 8.5	2,900/1,171				
4	10	0.5 - 1.0	1/21		10/1/93	10/1/93	VMP-1
		2.5 - 3.0	17/142				
		4.0 - 4.5	2,500/1,330				
		6.5 - 7.0	7,000/2,087				
		7.0 - 7.5	NR/NR	B2034-VMP1-7			
		9.5 - 10.0	2,400/1,333				
5	10	0.5 - 1.0	3/8.7		10/4/93	10/4/93	VMP-3
		3.0 - 3.5	10/23				
		5.0 - 5.5	8/13				
		6.5 - 7.0	6/4				
		7.5 - 8.0	8/3				
		8.5 - 9.0	790/275				
		9.5 - 10.0	390/324				

NR = Not Recorded

06/10/94

b34.xls



GEOLOGIC CROSS-SECTION
BUILDING 2034

FAIRCHILD AIR FORCE BASE, WASHINGTON

FIGURE 1.11

REV. 3 C274-01.DWG 05/20/94

ENGINEERING-SCIENCE, INC.

TABLE 1.8
VMP/VW CONSTRUCTION DATA
Building 2034
Fairchild AFB, Washington

WELL ID #	BOREHOLE TOTAL DEPTH (ft.bgs)	VW SCREEN INTERVAL (ft.bgs)	CENTER of VMP SCREEN (ft.bgs)	FILTER PACK INTERVAL(s) (ft.bgs)	BENTONITE INTERVAL(s) (ft.bgs)	GROUT INTERVAL(s) (ft.bgs)
VW-1	10	5.0 - 10.0	-	4.5 - 10.0	2.5 - 4.5	2.0 - 2.5
VMP-1	10	-	4.0	3.5 - 4.5	2.0 - 3.5	1.5 - 2.0
			7.0	6.5 - 7.5	4.5 - 6.5	
					7.5 - 10.0	
VMP-2	10	-	4.0	3.5 - 4.5	2.0 - 3.5	1.5 - 2.0
			7.0	6.5 - 7.5	4.5 - 6.5	
					7.5 - 10.0	
VMP-3	10	-	5.0	4.5 - 5.5	2.0 - 4.5	1.5 - 2.0
			8.5	8.5 - 9.0	5.5 - 8.5	
					9.0 - 10.0	

06/10/94

b34.xls

VW-1 was connected to the blower unit by 2-inch diameter Schedule 40 PVC pipe buried in a trench. The trench, approximately 15 feet long, 8 inches wide, and 1 foot deep, was excavated from the blower location to VW-1. After securing the pipe, soil was returned to the trench and compacted.

The horizontal pipe was elbowed below ground at the designated blower location and the top of the vertical PVC pipe was cut to approximately two feet above ground surface. The above ground PVC pipe was connected directly to the portable blower unit for the initial pilot test and then to the fixed blower unit for the extended pilot test.

1.7.4 Vapor Monitoring Points

VMP-1, VMP-2, and VMP-3 were installed at distances from VW-1 of 10 feet, 20 feet, and 32.5 feet, respectively (Figure 1.10). VMP-1 and VMP-2 were located along a line north of VW-1, and VMP-3 was located northeast of VW-1, along the assumed direction of groundwater flow from the original UST location (see Part I, Section 2.3).

All VMPs were installed following procedures described in the protocol document and as detailed in Section 1.2. Site-specific construction details for the VMPs installed at Building 2034 are contained in Table 1.8 and Figure 1.2. All three VMPs have nearly identical construction details with only slight variations in actual screened intervals. The center of the screened intervals for each VMP are located as follows: 4 and 7 feet bgs for VMP-1; 4 and 7 feet bgs for VMP-2; and 5 and 8.5 feet bgs for VMP-3.

The surface completion of the VMPs consisted of a 12-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 2.5-foot diameter concrete collar.

1.7.5 Blower Unit

The fixed regenerative blower unit was installed on 15 October 1993 and began operation on 9 March 1994 for the extended pilot test at Building 2034. At the time of installation, the fixed blower unit was injecting approximately 28 scfm. The unit is powered by a line installed by an electrical subcontractor which runs to the blower from the inside of Building 2034.

1.7.6 Exceptions to Protocol Document Procedures

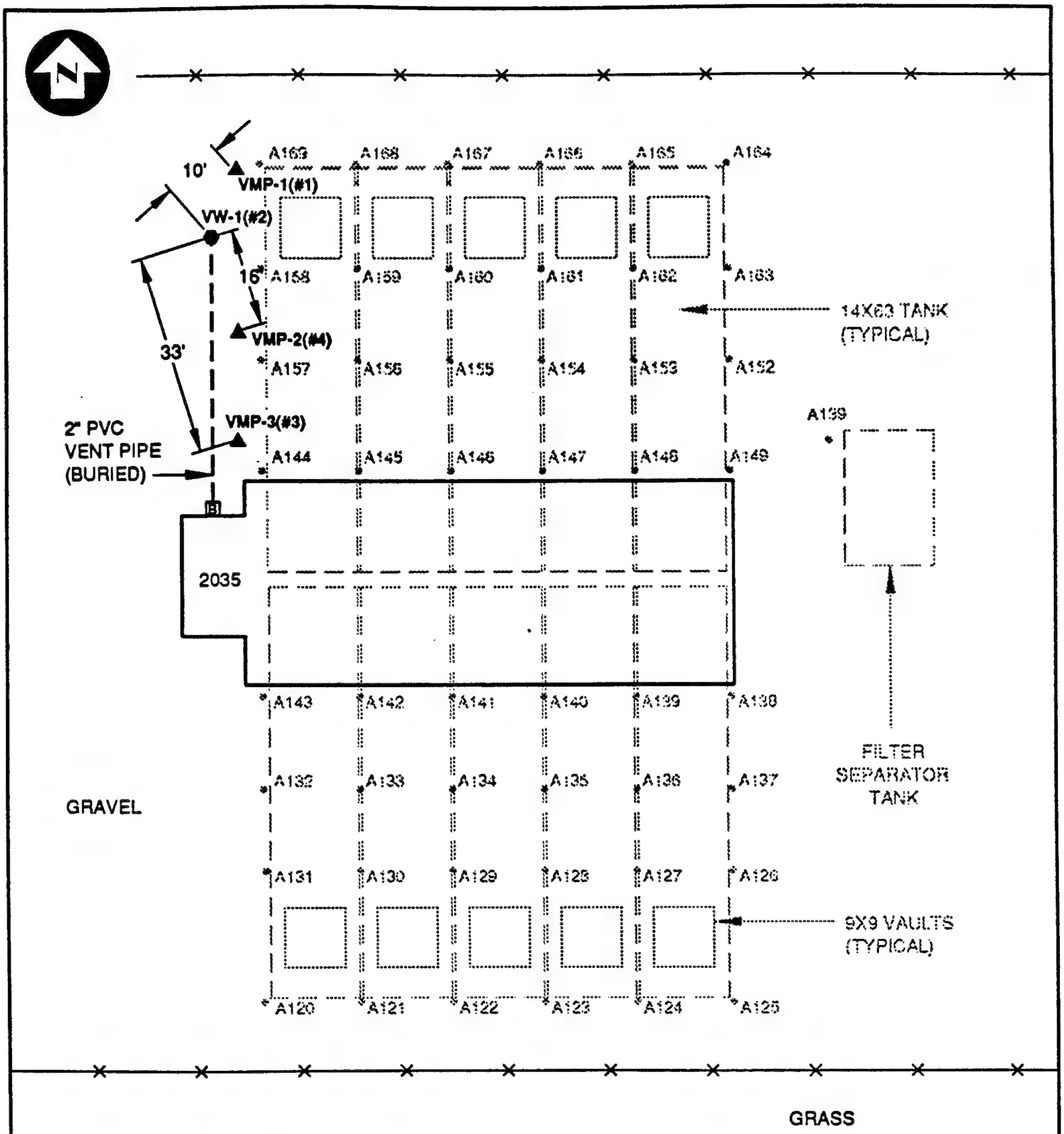
Protocol document procedures related to pilot test design and construction were followed with no significant exceptions.

1.8 Building 2035

1.8.1 Introduction

Installation of one VW (VW-1) and three VMPs (VMP-1, VMP-2, and VMP-3) was conducted at Building 2035 between 4 and 12 October 1993. Locations of the VWs and VMPs are shown on Figure 1.12. Five boreholes were drilled at the site and all were converted to either a VW or a VMP. Table 1.9 summarizes pertinent borehole data.

FIGURE 1.12



EXPLANATION

	FENCE
*A120	SOIL GAS PROBE LOCATION
	UNDERGROUND FUEL STORAGE TANK
B	BLOWER LOCATION
VW-1 (#2)	VENT WELL AND SOIL (AND SOIL BORING NUMBER)
VMP-2 (#4)	VAPOR MONITORING POINT (AND SOIL BORING NUMBER)

SOURCE: MODIFIED FROM HALLIBURTON NUS (1993)

0 12.5 25
SCALE IN FEET

AS-BUILT VENT WELL AND VAPOR MONITORING POINT LOCATIONS BUILDING 2035

FAIRCHILD AIR FORCE BASE, WASHINGTON

REV. 1 C273-04.DWG 05/20/94

ENGINEERING-SCIENCE, INC.

TABLE 1.9
BOREHOLE, SOIL SAMPLE, AND VMP/VW SUMMARY DATA
Building 2035
Fairchild AFB, Washington

BOREHOLE ID #	BOREHOLE TOTAL DEPTH (ft. bgs)	SOIL SAMPLE INTERVAL (ft. bgs)	THVA/PID HEADSPACE READINGS (ppmv)	SOIL SAMPLE ID #	START DATE	COMPLETION DATE	COMPLETION DESIGNATION
1	10	0.5 - 1.0	0/0		10/4/93	10/6/93	VMP-1
		2.5 - 3.0	0/0				
		4.5 - 5.0	8/0				
		6.5 - 7.0	96/0				
		7.0-8.0	NR/NR	B2035-VMP1-7			
		8.0 - 8.5	1,150/724				
2	10	0.5 - 1.0	0/0		10/4/93	10/5/93	VW-1
		3.0 - 3.5	0/0				
		4.5 - 5.0	9/0				
		6.0 - 6.5	12/2				
		7.5 - 8.0	840/503				
		8.0-9.0	NR/NR	B2035-VW1-8			
		9.0 - 9.5	6,400/2,430				
3	10	1.5 - 2.0	0/0		10/5/93	10/12/93	VMP-3
		2.5 - 3.0	0/0				
		4.5 - 5.0	0/0				
		6.5 - 7.0	740/623				
		8.5 - 9.0	2,500/2,217				
4	10	0.5 - 1.0	2/15		10/6/93	10/12/93	VMP-2
		2.5 - 3.0	7/15				
		4.5 - 5.0	16/19				
		6.0 - 6.5	38/16				
		8.5 - 9.0	3,000/765	B2035-VMP2-8.5			

NR = Not Recorded

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1.8.2 Soil Profile

Figure 1.13 is a geologic cross-section of the pilot test site using data from the VW and the three VMPs. The interpreted soil profile is shown along with OVA readings, VW and VMP screened intervals, TRPH concentrations from laboratory analysis of soil samples, and initial oxygen levels in soil gas. The soil boring logs are included in Appendix A.

The observed soil profile in VW-1, VMP-1 and VMP-2 from surface to a depth of 1 foot bgs is a dark brown silty sand with occasional gravel and/or clay. Beneath this sand and gravel layer and below ground surface in VMP-3 is a brown to brownish black predominantly silty sand with occasional gravel and/or clay. This silty sand extends to a depth of 6.5 feet bgs in VMP-1 and VMP-3 and to approximately 8 feet bgs in VW-1 and VMP-2; however, a brown silty sand and gravel layer that grades laterally to a sand is found in VW-1, VMP-2 and VMP-3 from about 2 to 4 feet bgs, and a brown silty sand and gravel layer is found in VMP-3 from approximately 4.5 to 5.5 feet bgs. The extensive silty sand interval exhibited a noticeable fuel odor in VMP-2 from approximately 6 to 8 feet below ground surface.

A black-brown to gray-brown clayey silt/sand occurs in VMP-1 from 6.5 to 8 feet bgs, in VW-1 from approximately 7.5 to 8.5, and at the base of VMP-2. Noticeable fuel odors were exhibited in VMP-2 in this material. A black sand exists from 6.5 feet below ground surface to the bottom of the borehole in VMP-3. This sand exhibited noticeable fuel odors.

Groundwater was encountered in VW-1 and VMP-1; groundwater levels are shown on Figure 1.13. Initial encountered levels were 9 feet bgs in both VW-1 and VMP-1. Possible free product was encountered at 9.5 to 10 feet bgs in VMP-1.

1.8.3 Air Injection Vent Well

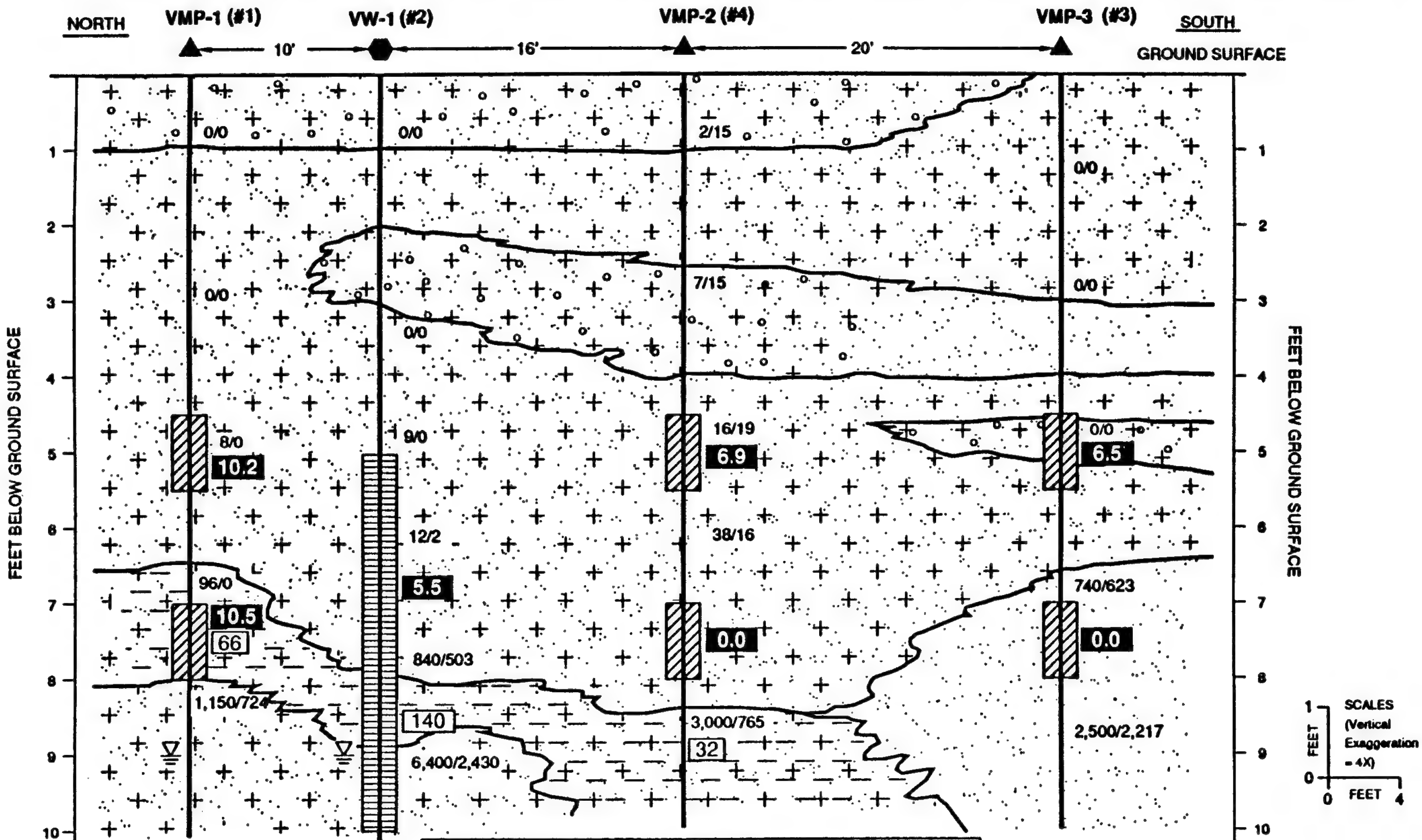
One air injection VW (VW-1) was installed following procedures described in Section 1.1. VW-1 was installed approximately 40 feet north of the western portion of Building 2035, immediately east of the underground tank complex (Figure 1.12). The screen was set between 5 and 10 feet bgs. Site-specific construction details for the VW installed at Building 2035 are contained in Table 1.10 and Figure 1.1.

The surface completion of the VW consisted of an 18-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 3-foot diameter concrete collar.

VW-1 was connected to the blower unit by 2-inch diameter Schedule 40 PVC pipe buried in a trench. The trench, approximately 40 feet long, 8 inches wide, and 1 foot deep, was excavated from the blower location to VW-1. After securing the pipe, soil was returned to the trench and compacted.

The horizontal pipe was elbowed below ground at the designated blower location and the top of the vertical PVC pipe was cut to approximately two feet above ground surface. The above ground PVC pipe was connected directly to the portable blower unit for the initial pilot test and then to the fixed blower unit for the extended pilot test.

FIGURE 1.13



LITHOLOGIC DESCRIPTION

- SILTY SAND AND GRAVEL
- SAND (with occasional silt/gravel)
- PREDOMINANTLY SILTY SAND (with occasional gravel/clay)
- CLAYEY SILT, CLAYEY SAND
- CLAY

EXPLANATION

- VMP-2 (#3) — VAPOR MONITORING POINT (and Soil Boring Number)
- VW-1 (#1) — VENT WELL (and Soil Boring Number)
- 120/435 — FIELD OVA (SOIL) DATA: THVA/PID (ppm)
- WATER LEVEL
- 10.2 — INITIAL O_2 CONCENTRATION IN SOIL GAS (%)
- 14 — LABORATORY SOIL SAMPLE: TRPH (mg/kg)
- GEOLOGIC CONTACT
- VMP FILTER PACK (SCREEN) INTERVAL
- VW SCREENED INTERVAL

GEOLOGIC CROSS-SECTION BUILDING 2035

FAIRCHILD AIR FORCE BASE, WASHINGTON

TABLE 1.10
VMP/VW CONSTRUCTION DATA
Building 2035
Fairchild AFB, Washington

WELL ID #	BOREHOLE TOTAL DEPTH (ft.bgs)	VW SCREEN INTERVAL (ft.bgs)	CENTER of VMP SCREEN (ft.bgs)	FILTER PACK INTERVAL(s) (ft.bgs)	BENTONITE INTERVAL(s) (ft.bgs)	GROUT INTERVAL(s) (ft.bgs)
VW-1	10	5 - 10	-	4.5 - 10	2.5 - 4.5	2.0 - 2.5
VMP-1	10	-	5.0	4.5 - 5.5	2.0 - 4.5	1.5 - 2.0
			7.5	7.0 - 8.0	5.5 - 7.0	
					8.0 - 10.0	
VMP-2	10	-	5.0	4.5 - 5.5	2.0 - 4.5	1.5 - 2.0
			7.5	7.0 - 8.0	5.5 - 7.0	
					8.0 - 10.0	
VMP-3	10	-	5.0	4.5 - 5.5	2.0 - 4.5	1.5 - 2.0
			7.5	7.0 - 8.0	5.5 - 7.0	
					8.0 - 10.0	

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1.8.4 Vapor Monitoring Points

VMP-1, VMP-2, and VMP-3 were installed at distances from VW-1 of 10 feet, 16 feet, and 33 feet, respectively (Figure 1.10). All three VMPs were located along a north-south line immediately east of the underground tank complex.

All VMPs were installed following procedures described in the protocol document and as detailed in Section 1.2. Site-specific construction details for the VMPs installed at Building 2035 are contained in Table 1.10 and Figure 1.2. All three VMPs have identical construction details. The center of the screened intervals for each VMP are located at 5 and 7.5 feet bgs.

The surface completion of the VMPs consisted of a 12-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 2.5-foot diameter concrete collar.

1.8.5 Blower Unit

The fixed regenerative blower unit was installed on 21 October 1993 and began operation on 9 March 1994 for the extended pilot test at Building 2035. At the time of installation, the fixed blower unit was injecting approximately 25 scfm. The unit is powered by a line installed by an electrical subcontractor which runs to the blower from the inside of Building 2035.

1.8.6 Exceptions to Protocol Document Procedures

Protocol document procedures related to pilot test design and construction were followed with no significant exceptions.

1.9 Background Wells

1.9.1 Introduction

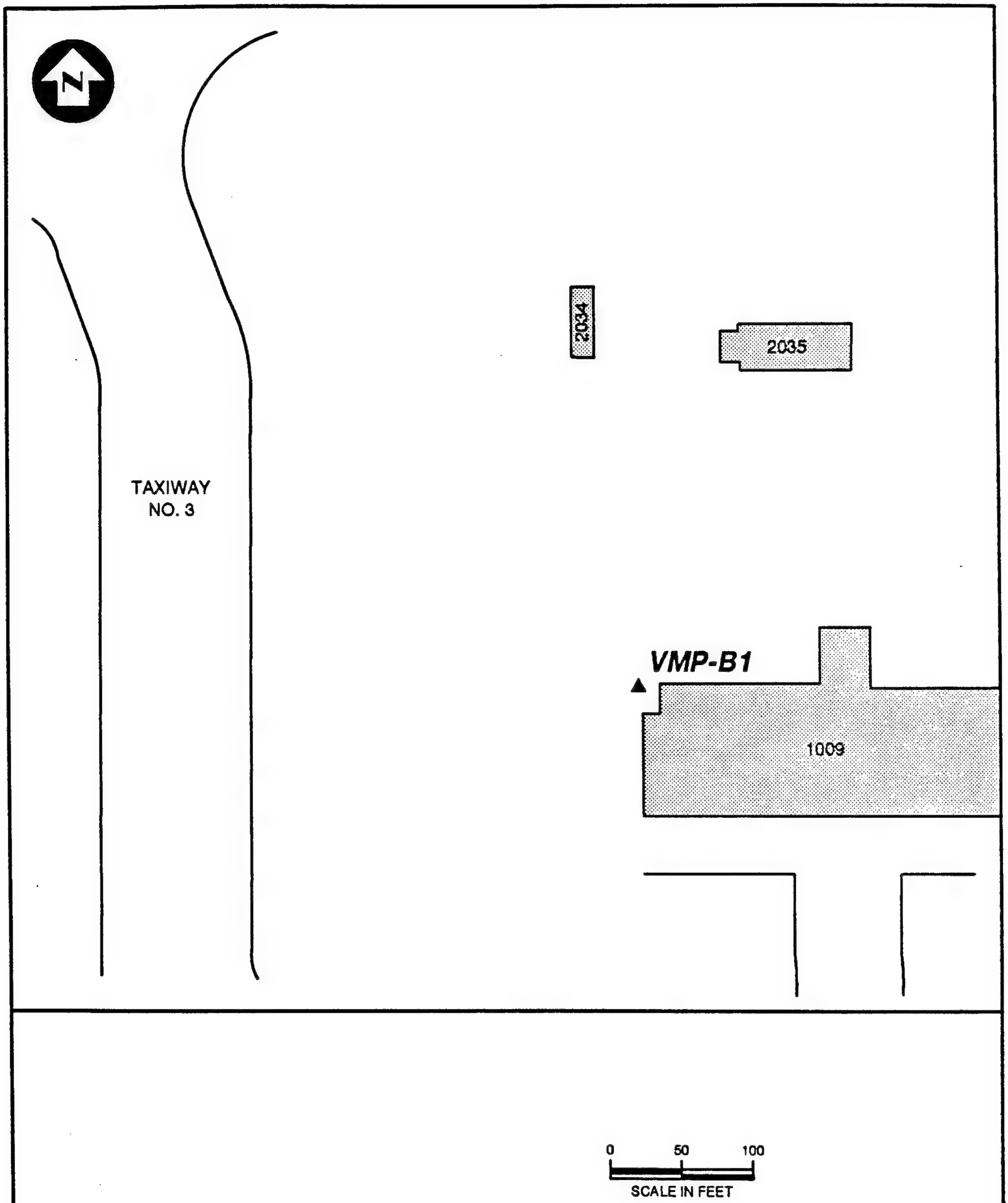
Installation of two background VMPs (VMP-B1 and VMP-B2) was conducted on 23 October 1993. VMP-B1 was installed near the northwest corner of Building 1009 (Figure 1.14) and serves as the background VMP for PS-2, Building 2034, and Building 2035. VMP-B2 was installed just off the asphalt parking lot northwest of the base veterinary clinic, Building 2428 (Figure 1.15) and serves as the background VMP for PS-1A and PS-1B. Only one borehole was drilled at each location and it was converted to the background VMP. Table 1.11 summarizes pertinent borehole data.

1.9.2 Soil Profile

The soil boring logs for the two boreholes converted to background VMPs, VMP-B1 and VMP-B2, are included in Appendix A.

The boring for VMP-B1 was advanced to a total of 8 feet bgs. The observed soil profile from surface to 2 feet bgs is brown silty sand and gravel. From 2 feet bgs to 6.5 feet bgs is a brown to dark brown silty sand with occasional gravel and clay. A sand and gravel interval occurs from 6.5 feet bgs to the base of the borehole. This soil profile is similar to the soil profiles of PS-2, Building 2034 and Building 2035, where an upper

FIGURE 1.14



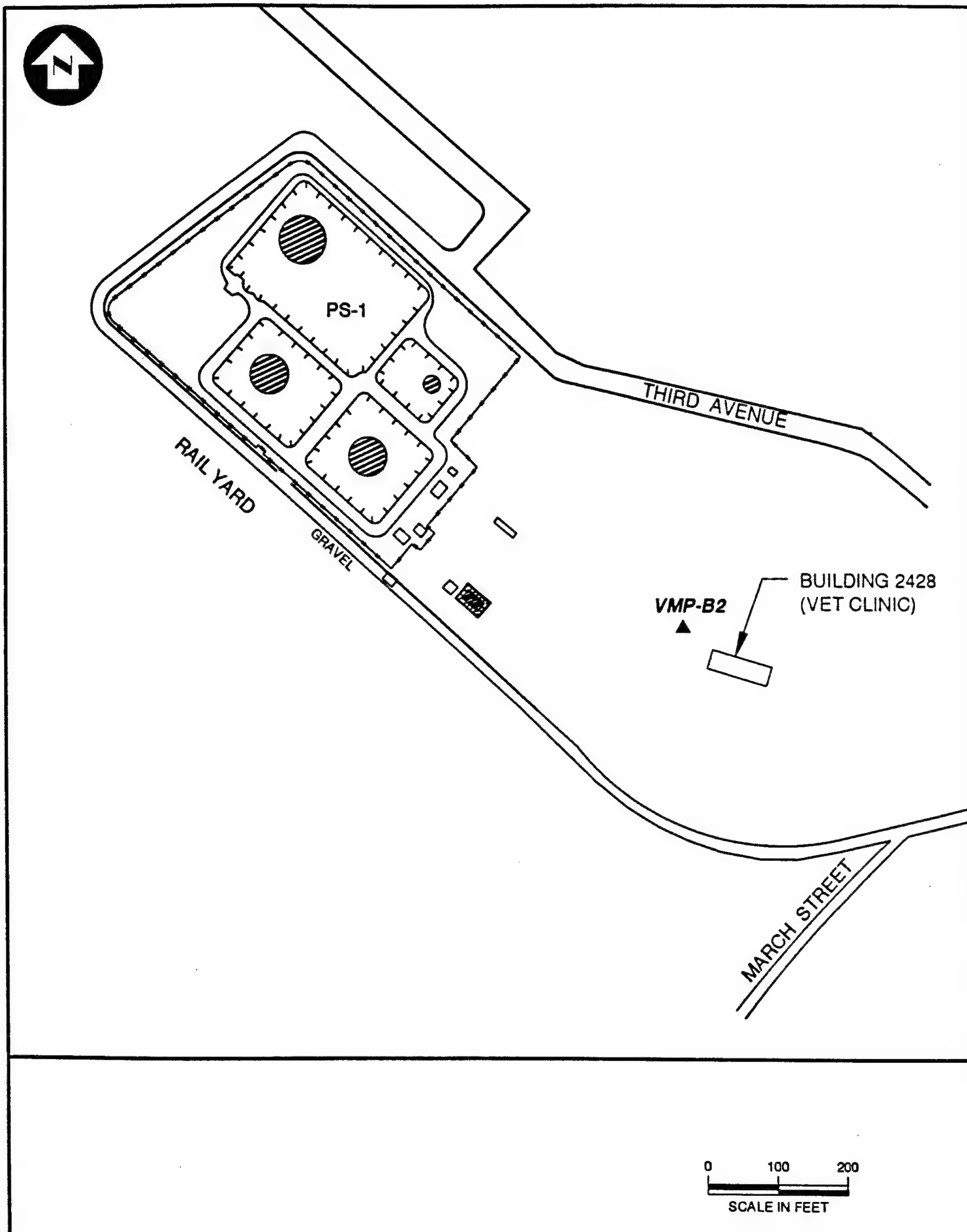
AS BUILT BACKGROUND VMP LOCATION
PS-2, BUILDING 2034, AND BUILDING 2035

FAIRCHILD AIR FORCE BASE,
WASHINGTON

REV. 2 C341-08.DWG 06/10/94

ENGINEERING-SCIENCE, INC.

FIGURE 1.15



AS BUILT BACKGROUND VMP LOCATION PS-1A AND PS-1B

FAIRCHILD AIR FORCE BASE, WASHINGTON

SOURCE: MODIFIED FROM FAIRCHILD AFB (1993)

REV. 2 C341-06.DWG 06/09/94

ENGINEERING-SCIENCE, INC.

TABLE 1.11
BOREHOLE, SOIL SAMPLE, AND VMP SUMMARY DATA
Background Wells
Fairchild AFB, Washington

BOREHOLE ID #	BOREHOLE TOTAL DEPTH (ft. bgs)	SOIL SAMPLE INTERVAL (ft. bgs)	THVA/PID HEADSPACE READINGS (ppmv)	SOIL SAMPLE ID #	START DATE	COMPLETION DATE	COMPLETION DESIGNATION
VMP-B1	8	0.5 - 1.0	0/NR		10/23/93	10/23/93	VMP-B1
		1.0 - 1.5	0/NR				
		1.5 - 2.0	0/NR				
		2.5 - 3.0	0/NR				
		3.0 - 3.5	0/NR				
		3.5 - 4.0	2/NR				
		4.5 - 5.0	NR/NR	B1009-VMPB1-5			
		5.0 - 5.5	4/NR				
		5.5 - 6.0	2/NR				
		6.5 - 7.0	0/NR				
		7.0 - 7.5	0/NR				
		7.5 - 8.0	0/NR				
VMP-B2	8	1.0 - 1.5	0/NR		10/23/93	10/23/93	VMP-B2
		1.5 - 2.0	1/NR				
		3.0 - 3.5	1/NR				
		3.5 - 4.0	1/NR				
		5.0 - 5.5	1/NR				
		5.5 - 6.0	NR/NR	PS1-VMPB2-5			
		6.0 - 6.5	1/NR				
		6.5 - 7.0	2/NR				
		7.0 - 7.5	1/NR				
		7.5 - 8.0	2/NR				

NR = Not Recorded

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layer of predominantly sand and gravel extends from surface to approximately 1 to 2 feet bgs, and a lower layer of predominantly silty sand extends to a depth of approximately 6 to 8 feet bgs.

The boring for VMP-B2 was advanced to a total of 8 feet bgs. The observed soil profile from surface to 6 feet bgs is brown sand with occasional silt and gravel. A dark brown sand interval occurs from 6 feet bgs to the base of the borehole. This soil profile is similar to the soil profiles of PS-1A and PS-1B, where an upper layer of predominantly sand with silt is underlain by predominantly sand.

At both background sites, no contamination was observed in the physical feature of the soil or determined based on the OVA readings. No groundwater was encountered during drilling operations at either site.

1.9.3 Vapor Monitoring Points

Both background VMPs were installed following procedures described in the protocol document and as detailed in Section 1.2. Site-specific construction details for the background VMPs are contained in Table 1.12 and Figure 1.2. Both background VMPs have nearly identical construction details with only slight variations in actual screened intervals. The center of the screened intervals for each VMP are located as follows: 5 and 7.5 feet bgs for VMP-B1 and 3 and 5.5 feet bgs for VMP-B2.

The surface completion of the VMPs consisted of a 12-inch diameter, water-tight, traffic-proof, cast-iron well box (securable with hexbolts) emplaced within a 2.5-foot diameter concrete collar.

1.9.4 Exceptions to Protocol Document Procedures

Protocol document procedures related to pilot test design and construction were followed with no significant exceptions.

TABLE 1.12
VMP CONSTRUCTION DATA
Background Wells
Fairchild AFB, Washington

WELL ID #	BOREHOLE TOTAL DEPTH (ft.bgs)	VW SCREEN INTERVAL (ft.bgs)	CENTER of VMP SCREEN (ft.bgs)	FILTER PACK INTERVAL(s) (ft.bgs)	BENTONITE INTERVAL(s) (ft.bgs)	GROUT INTERVAL(s) (ft.bgs)
VMP-B1	8	-	5.0	4.5-5.5	1.5-4.5	1.0-1.5
			7.5	7.0-8.0	5.5-7.0	
VMP-B2	8	-	3.0	2.5-3.5	1.5-2.5	1.0-1.5
			5.5	5.0-6.0	3.5-5.0	
					6.0-8.0	

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2.0 SOIL, SOIL-GAS, AND SURFACE AIR SAMPLING RESULTS

2.1 Soil Sample Field Analysis and Laboratory Analysis

At all five sites, contaminated soils were identified based on field observations such as visual appearance, odor, and OVA readings of soil sample headspace as described in the protocol document. OVA readings were monitored using both a PID and a THVA on soil samples in order to estimate the relative amount and extent of soil contamination detectable by such devices.

Soil samples were collected using a continuous split-spoon sampler lined with brass or stainless steel sleeves. The samples were preserved in the brass or stainless steel sleeves and capped with Teflon™ tape and plastic end caps. Selection of soil samples for laboratory analysis was based on field OVA readings, visual appearance, and odor.

Soil samples selected for laboratory analysis were delivered by Federal Express™ to PACE, Inc. in Novato, California for chemical and physical analysis. Chain-of-custody forms are included in Appendix C. Analytes for all soil samples collected at the five bioventing sites were: total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene, and total xylenes (BTEX); iron; total alkalinity; pH; total Kjeldahl nitrogen (TKN); total phosphorus; moisture content; and grain-size distribution. Samples to be analyzed for TKN, total phosphorus, and grain-size distribution were transferred to Sequoia Analytical in Redwood City, California.

The locations where soil samples were collected and the analytical results are discussed in the site-specific sections (Sections 2.3 through 2.8).

2.2 Soil-Gas/Surface Air Sample Laboratory Analysis

Subsurface soil-gas samples were collected in VWs and VMPs for laboratory analysis in one-liter Summa® canisters after purging the individual casings and filter packs of at least one volume of air. The soil-gas samples were shipped to Air Toxics, Ltd. in Folsom, California for analysis of total volatile hydrocarbons as jet fuel (TVH-jf) and BTEX. Chain-of-custody forms are included in Appendix C.

At Building 2034 and Building 2035, surface air samples were collected for laboratory analysis in one-liter Summa® canisters before and during air injection to estimate potential emissions of TVH-jf and BTEX to the atmosphere resulting from air injection during the pilot test. Surface measurements were taken using an isolation flux chamber and followed protocols established by the Environmental Protection Agency's Environmental Monitoring Systems Laboratory (EPA, February 1986). Hydrocarbon emissions were measured using both the THVA and laboratory analyses. The surface air samples were also shipped to Air Toxics, Ltd. for analysis of total volatile hydrocarbons as jet fuel (TVH-jf) and BTEX and chain-of-custody forms are included in Appendix C.

The locations where soil-gas and surface air samples were collected and the analytical results are discussed in the site-specific sections (Sections 2.3 through 2.8).

2.3 PS-2

2.3.1 Soil Sample Field Analysis and Laboratory Analysis

Soil sample headspace OVA readings for PS-2 were previously given in Table 1.1. Soil samples were collected and analyzed using the procedures described in Section 2.1. Samples were collected at VW-1, VMP-1, and VMP-2 from depths of 7.5, 4, and 5 feet bgs, respectively. The results of all analyses for PS-2 samples are summarized in Table 2.1 and discussed below. The TRPH concentrations are also included on the geologic cross section (Figure 1.5).

2.3.2 Soil-Gas Sample Laboratory Analysis

Soil-gas samples were collected and analyzed using the procedures described in Section 2.2. Samples were collected from the vent well (VW-1) and from the screened intervals at 4 and 7 feet bgs in VMP-1 and VMP-3, respectively. Results of these analyses are summarized in Table 2.1 and discussed below.

2.3.3 Field QA/QC Results

No Quality Assurance/Quality Control (QA/QC) soil or soil-gas samples (field duplicates) were collected during sampling activities at PS-2.

2.3.4 Subsurface Contamination

The extent of the hydrocarbon contamination at the site remains unknown. All boreholes drilled at the site encountered evidence of hydrocarbon contamination. OVA readings greater than 8,000 ppmv were measured in all boreholes. The highest OVA readings were generally recorded between 2 and 5 feet bgs, below the gravely sand interval and within the silty sand interval (see Figure 1.5). Fuel odors were noted in all borings from just below the surface to the bottom of the borehole.

Laboratory analysis of soil and soil-gas samples documented hydrocarbon contamination in all wells. The maximum contaminant levels in soil were: 980 mg/kg TRPH (VMP2-5), 4.1 mg/kg benzene (VMP1-4), 0.5 mg/kg toluene (VW1-7.5), 21 mg/kg ethylbenzene (VMP1-4), and 120 mg/kg total xylenes (VMP1-4). The maximum contaminant levels in soil gas were: 170,000 ppmv TVH-jf, 400 ppmv benzene, 93 mg/kg toluene, 42 ppmv ethylbenzene, and 190 ppmv total xylenes (all at VMP3-7). The soil results are consistent with the results from previous investigations (see Part I, Section 2.1). The very high contaminant levels in soil gas are probably due to the floating product which exists at the site and the shallow groundwater table. Floating product was measured at 1.0 feet in thickness in MW-177 (approximately 100 feet south of the pilot test site) on 20 October 1993 during ES field work.

2.3.5 Exceptions To Protocol Document Procedures

Protocol document procedures related to soil and soil-gas sampling were followed with no significant exceptions.

TABLE 2.1
SOIL and SOIL GAS ANALYTICAL RESULTS
PS-2
Fairchild AFB, Washington

ANALYTE	METHOD	UNITS	SAMPLE LOCATION - DEPTH (WELL NUMBER AND FEET BELOW GROUND SURFACE)		
Soil Hydrocarbons:			**VW1-7.5**	**VMP1-4**	**VMP2-5 [1]**
TRPH	EPA 418.1	(mg/kg)	250	280	980
Benzene	SW8020	(mg/kg)	0.7	4.1	0.14
Toluene	SW8020	(mg/kg)	0.5	<0.49	<0.051
Ethylbenzene	SW8020	(mg/kg)	7.2	21	0.71
Xylenes, Total	SW8020	(mg/kg)	47	120	3.8
Soil Inorganics:			**VW1-7.5**	**VMP1-4**	**VMP2-5 [1]**
Iron	SW7380	(mg/kg dry wt.)	23,500	26,100	18,000
Total Alkalinity	SM403	(mg/kg as $CaCO_3$)	580	360	74
pH	SW9045	(units)	7.6	8.1	7
TKN	E351.2	(mg/kg dry wt.)	610	190	130
Total Phosphorus	E365.2	(mg/kg dry wt.)	80	170	92
Soil Physical Parameters:			**VW1-7.5**	**VMP1-4**	**VMP2-5 [1]**
Moisture Content	ASTM D2216	(% by wt.)	15	5.5	9.3
Gravel	ASTM D422	(% by wt.)	4.7	22.9	1.0
Sand	ASTM D422	(% by wt.)	46.6	54.1	64.9
Silt	ASTM D422	(% by wt.)	39.9	14.7	27.0
Clay	ASTM D422	(% by wt.)	8.9	8.2	7.2
Soil Gas Hydrocarbons:			**VW1**	**VMP1-4**	**VMP3-7**
TVH-jf	EPA TO-3	(ppmv)	110,000	78,000	170,000
Benzene	EPA TO-3	(ppmv)	150	160	400
Toluene	EPA TO-3	(ppmv)	<3.7	<2.3	93
Ethylbenzene	EPA TO-3	(ppmv)	24	31	42
Xylenes, Total	EPA TO-3	(ppmv)	130	130	190

NOTES:

TRPH - Total recoverable petroleum hydrocarbons
TVH-jf - Total volatile hydrocarbons as jet fuel
TKN - Total Kjeldahl nitrogen
ppmv - Parts per million by volume
[1] - Sample labelled as VMP2-4, but collected at 5 ft bgs

$CaCO_3$ - Calcium carbonate
mg/kg - milligrams per kilogram
NA - Not Analyzed

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2.4 PS-1A

2.4.1 Soil Sample Field Analysis and Laboratory Analysis

Soil sample headspace OVA readings for PS-1A were previously given in Table 1.3. Soil samples were collected and analyzed using the procedures described in Section 2.1. Samples were collected at VW-1, VMP-2, and VMP-3 from depths of 6, 4, and 6 feet bgs, respectively. An additional soil sample was collected from VW-1 at 7 feet bgs. The results of all analyses for PS-1A samples are summarized in Table 2.2 and discussed below. The TRPH concentrations are also included on the geologic cross section (Figure 1.7).

2.4.2 Soil-Gas Sample Laboratory Analysis

Soil-gas samples were collected and analyzed using the procedures described in Section 2.2. Samples were collected from the vent well (VW-1) and from the screened intervals at 6 and 5.5 feet bgs in VMP-1 and VMP-3, respectively. Results of these analyses are summarized in Table 2.2 and discussed below.

2.4.3 Field QA/QC Results

As noted above, an additional soil sample was collected from the VW-1 borehole at approximately 7 feet bgs. Soil hydrocarbon analytes were the same for this additional sample as for the sample collected at 6 feet bgs (see Table 2.2).

The two samples at 6 and 7 feet bgs resulted in very different measurements of fuel hydrocarbons. These results are probably due to a heterogeneous distribution of fuel-hydrocarbon contamination. Support for this interpretation is evidenced by the fact that the samples were separated by a depth of one foot and OVA readings changed significantly between the two depths where the samples were collected (see Table 1.3).

A duplicate soil-gas sample (field duplicate) was collected from VW-1. The duplicate sample was labeled "VW2" so that the laboratory would not be able to identify the sample as a duplicate. Analytes were the same for the duplicate sample as for the regular sample (see Table 2.2). The two samples resulted in nearly identical measurements for volatile organics.

2.4.4 Subsurface Contamination

The extent of the hydrocarbon contamination at the site remains unknown. All boreholes drilled at the site encountered evidence of hydrocarbon contamination. OVA readings greater than 6,000 ppmv were measured in all boreholes. The highest OVA readings were generally recorded between 5 and 7 feet bgs, just above the groundwater table in the sand interval (see Figure 1.7). Fuel odors were noted in all borings, although odors were not as prevalent in VMP-3.

Laboratory analysis of soil and soil-gas samples documented hydrocarbon contamination in all wells. The maximum contaminant levels in soil were: 5,660 mg/kg TRPH, 5.6 mg/kg benzene, 91 mg/kg toluene, 56 mg/kg ethylbenzene, and 340 mg/kg total xylenes (all at VW1-7). The maximum contaminant levels in soil gas were: 26,000 ppmv TVH-jf (VMP1-6), 17 ppmv ethylbenzene (VW1), and 110 ppmv total xylenes

TABLE 2.2
SOIL and SOIL GAS ANALYTICAL RESULTS
PS-1A
Fairchild AFB, Washington

ANALYTE	METHODS	UNITS	SAMPLE LOCATION - DEPTH (WELL NUMBER AND FEET BELOW GROUND SURFACE)			
Soil Hydrocarbons:			VW1-6	VW1-7 [1]	VMP2-4	VMP3-6
TRPH	E418.1	(mg/kg)	390	5,660	1,940	140
Benzene	SW8020	(mg/kg)	<1.3	5.6	<0.5	<1.3
Toluene	SW8020	(mg/kg)	11	91	11	7.7
Ethylbenzene	SW8020	(mg/kg)	6.7	56	<0.5	3.9
Xylenes, Total	SW8020	(mg/kg)	44	340	49	22
Soil Inorganics:			VW1-6	VW1-7 [1]	VMP2-4	VMP3-6
Iron	SW7380	(mg/kg dry wt.)	23,500	NA	13,800	19,800
Total Alkalinity	SM403	(mg/kg as $CaCO_3$)	<44	NA	250	<43
pH	SW9045	(units)	6.7	NA	7.6	6.8
TKN	E351.2	(mg/kg dry wt.)	74	NA	1,200	99
Total Phosphorus	E365.2	(mg/kg dry wt.)	470	NA	280	280
Soil Physical Parameters:			VW1-6	VW1-7 [1]	VMP2-4	VMP3-6
Moisture Content	ASTM D2216	(% by wt.)	9.9	16	6.8	6.3
Gravel	ASTM D422	(% by wt.)	3.7	NA	0.5	3.0
Sand	ASTM D422	(% by wt.)	79.8	NA	54.0	62.4
Silt	ASTM D422	(% by wt.)	13.3	NA	39.3	27.5
Clay	ASTM D422	(% by wt.)	3.3	NA	6.2	7.2
Soil Gas Hydrocarbons:			VW1	VW1 [2]	VMP1-6	VMP3-5.5
TVH-jf	EPA TO-3	(ppmv)	23,000	25,000	26,000	11,000
Benzene	EPA TO-3	(ppmv)	<2.2	<2.2	<2.2	<1.1
Toluene	EPA TO-3	(ppmv)	<2.2	<2.2	<2.2	<1.1
Ethylbenzene	EPA TO-3	(ppmv)	16	17	11	8.0
Xylenes, Total	EPA TO-3	(ppmv)	99	110	76	61

NOTES:

TRPH - Total recoverable petroleum hydrocarbons
TVH-jf - Total volatile hydrocarbons as jet fuel
TKN - Total Kjeldahl nitrogen
ppmv - Parts per million by volume
[1] - Sample labeled as VMP4-7
[2] - Duplicate sample labeled as VW2

$CaCO_3$ - Calcium carbonate
mg/kg - milligrams per kilogram
NA - Not Analyzed

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(VW1). Benzene and toluene was not detected in any soil gas samples. The soil and soil-gas results are consistent with the results from previous investigations (see Part I, Section 2.2).

2.4.5 Exceptions To Protocol Document Procedures

Procedures described in the protocol document related to soil and soil-gas sampling were used with the following exception:

- A soil sample was collected from VMP-3 instead of VMP-1 because of the higher OVA readings measured in the field.

2.5 PS-1B

2.5.1 Soil Sample Field Analysis and Laboratory Analysis

Soil sample headspace OVA readings for PS-1B were previously given in Table 1.5. No PID readings were recorded due to equipment problems. Soil samples were collected and analyzed using the procedures described in Section 2.1. Samples were collected at VW-1, VMP-1, and VMP-2 from depths of 6, 5.5, and 6 feet bgs, respectively. The results of all analyses for PS-1B samples are summarized in Table 2.3 and discussed below. The TRPH concentrations are also included on the geologic cross section (Figure 1.9).

2.5.2 Soil-Gas Sample Laboratory Analysis

Soil-gas samples were collected and analyzed using the procedures described in Section 2.2. Samples were collected from the vent well (VW-1) and from the screened intervals at 5 feet bgs in both VMP-1 and VMP-3. A duplicate soil-gas sample was collected at VMP1-5. Results of these analyses are summarized in Table 2.3 and discussed below.

2.5.3 Field QA/QC Results

A duplicate soil-gas sample (field duplicate) was collected at VMP-1 from the screen at 5 feet bgs. The duplicate sample was labeled "VMP4-5" so that the laboratory would not be able to identify the sample as a duplicate. Analytes were the same for the duplicate sample as for the regular sample (see Table 2.3). The two samples resulted in nearly identical measurements for volatile organics.

2.5.4 Subsurface Contamination

The extent of the hydrocarbon contamination at the site remains unknown. All boreholes drilled at the site encountered evidence of hydrocarbon contamination. OVA readings greater than 4,000 ppmv were measured in all boreholes. The highest OVA readings were generally recorded near the top of the sand interval, which varies at the site between 4 and 6 feet bgs (see Figure 1.9). Fuel odors were noted in all borings and generally were stronger with depth; however, fuel odors were not as prevalent in VMP-1.

Laboratory analysis of soil and soil-gas samples documented hydrocarbon contamination in all wells. The maximum contaminant levels in soil were: 1,580 mg/kg TRPH (VMP2-6), 0.010 mg/kg benzene (VW1-6), 62 mg/kg toluene (VMP1-5.5), 49

TABLE 2.3
SOIL and SOIL GAS ANALYTICAL RESULTS
PS-1B
Fairchild AFB, Washington

ANALYTE	METHODS	UNITS	SAMPLE LOCATION - DEPTH (WELL NUMBER AND FEET BELOW GROUND SURFACE)			
Soil Hydrocarbons:			VW1-6	VMP1-5.5	VMP2-6	
TRPH	E418.1	(mg/kg)	190	<5.8	1,580	
Benzene	SW8020	(mg/kg)	0.010	<5.8	<2.8	
Toluene	SW8020	(mg/kg)	0.023	62	10	
Ethylbenzene	SW8020	(mg/kg)	0.019	49	24	
Xylenes, Total	SW8020	(mg/kg)	0.26	190	130	
Soil Inorganics:			VW1-6	VMP1-5.5	VMP2-6	
Iron	SW7380	(mg/kg dry wt.)	17,900	23,100	23,200	
Total Alkalinity	SM403	(mg/kg as $CaCO_3$)	2,600	91	90	
pH	SW9045	(units)	7.9	7.5	7.7	
TKN	E351.2	(mg/kg dry wt.)	170	270	89	
Total Phosphorus	E365.2	(mg/kg dry wt.)	330	370	330	
Soil Physical Parameters:			VW1-6	VMP1-5.5	VMP2-6	
Moisture Content	ASTM D2216	(% by wt.)	17	14	12	
Gravel	ASTM D422	(% by wt.)	0.0	0.4	0.0	
Sand	ASTM D422	(% by wt.)	67.9	44.4	80.3	
Silt	ASTM D422	(% by wt.)	24.2	41.3	13.6	
Clay	ASTM D422	(% by wt.)	7.9	13.9	6.1	
Soil Gas Hydrocarbons:			VW1	VMP1-6	VMP1-6 [1]	VMP3-5
TVH-jf	EPA TO-3	(ppmv)	20,000	25,000	24,000	25,000
Benzene	EPA TO-3	(ppmv)	<1.1	<1.1	<1.1	92
Toluene	EPA TO-3	(ppmv)	90	81	77	95
Ethylbenzene	EPA TO-3	(ppmv)	6.7	11	12	24
Xylenes, Total	EPA TO-3	(ppmv)	32	59	54	110

NOTES:

TRPH - Total recoverable petroleum hydrocarbons
TVH-jf - Total volatile hydrocarbons as jet fuel
TKN - Total Kjeldahl nitrogen
ppmv - Parts per million by volume
[1] - Duplicate labeled as VMP4-5

$CaCO_3$ - Calcium carbonate
mg/kg - milligrams per kilogram
NA - Not Analyzed

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mg/kg ethylbenzene (VMP1-5.5), and 190 mg/kg total xylenes (VMP1-5.5). The maximum contaminant levels in soil gas were: 25,000 ppmv TVH-jf, 92 ppmv benzene, 95 ppmv toluene, 24 ppmv ethylbenzene, and 110 ppmv total xylenes (all at VMP3-5). The soil and soil-gas results are consistent with the results from previous investigations (see Part I, Section 2.2).

2.5.5 Exceptions To Protocol Document Procedures

Protocol document procedures related to soil and soil-gas sampling were followed with no significant exceptions.

2.6 Building 2034

2.6.1 Soil Sample Field Analysis and Laboratory Analysis

Soil sample headspace OVA readings for Building 2034 were previously given in Table 1.7. Soil samples were collected and analyzed using the procedures described in Section 2.1. Samples were collected at VW-1, VMP-1, and VMP-2 from depths of 5, 7, and 7 feet bgs, respectively. The results of all analyses for Building 2034 samples are summarized in Table 2.4 and discussed below. The TRPH concentrations are also included on the geologic cross section (Figure 1.11).

2.6.2 Soil-Gas/Surface Air Sample Laboratory Analysis

Soil-gas samples were collected and analyzed using the procedures described in Section 2.2. Samples were collected from the vent well (VW-1) and from the screened intervals at 7 and 8.5 feet bgs in VMP-1 and VMP-3, respectively. Results of these analyses are summarized in Table 2.4 and discussed below.

Additional surface air samples were collected for laboratory analysis before and during air injection to estimate potential emissions of TVH-jf and BTEX to the atmosphere resulting from air injection during the pilot test. Two samples were collected at a surface point (SPT) located 12 feet southeast of VW-1. One sample was collected prior to the start of air injection (sample SPT3B) and one sample approximately 4 hours after the start of and during air injection (sample SPT3A). The results of the surface air sample analyses are shown in Table 2.4 and discussed in Section 3.4.5.

2.6.3 Field QA/QC Results

No Quality Assurance/Quality Control (QA/QC) soil or soil-gas samples (field duplicates) were collected during sampling activities at Building 2034.

2.6.4 Subsurface Contamination

The extent of the hydrocarbon contamination at the site remains unknown. All boreholes drilled at the site encountered evidence of hydrocarbon contamination. OVA readings greater than 2,500 ppmv were measured in VW-1, VMP-1, and VMP-2. However, OVA readings did appear to decrease with distance from the original tank location. OVA readings were lower in VMP-3 and the abandoned borehole, although they were still above approximately 800 ppmv. The highest OVA readings were generally recorded within the silty sand at 7 to 9 feet bgs. Fuel odors were noted in all borings and generally were stronger with depth.

TABLE 2.4
SOIL, SOIL GAS, and SURFACE AIR ANALYTICAL RESULTS
Building 2034
Fairchild AFB, Washington

ANALYTE	METHOD	UNITS	SAMPLE LOCATION - DEPTH (WELL NUMBER AND FEET BELOW GROUND SURFACE)		
Soil Hydrocarbons:			VW1-5	VMP1-7	VMP2-7
TRPH	EPA 418.1	(mg/kg)	1,330	1,160	3,370
Benzene	SW8020	(mg/kg)	0.075	0.28	0.4
Toluene	SW8020	(mg/kg)	0.41	6.9	3
Ethylbenzene	SW8020	(mg/kg)	0.68	13	24
Xylenes, Total	SW8020	(mg/kg)	5.2	77	150
Soil Inorganics:			VW1-5	VMP1-7	VMP2-7
Iron	SW7380	(mg/kg dry wt.)	22,700	26,600	26,500
Total Alkalinity	SM403	(mg/kg as $CaCO_3$)	320	62	270
pH	SW9045	(units)	7.8	6.7	7.3
TKN	E351.2	(mg/kg dry wt.)	780	150	550
Total Phosphorus	E365.2	(mg/kg dry wt.)	660	1,800	490
Soil Physical Parameters:			VW1-5	VMP1-7	VMP2-7
Moisture Content	ASTM D2216	(% by wt.)	9.5	8.1	14
Gravel	ASTM D422	(% by wt.)	8.7	58.7	9.0
Sand	ASTM D422	(% by wt.)	51	33.6	57.9
Silt	ASTM D422	(% by wt.)	28.9	6.1	25.6
Clay	ASTM D422	(% by wt.)	11.3	1.6	7.5
Soil Gas Hydrocarbons:			VW1	VMP1-7	VMP3-8.5
TVH-jf	EPA TO-3	(ppmv)	23,000	29,000	570
Benzene	EPA TO-3	(ppmv)	<1.1	32	<0.55
Toluene	EPA TO-3	(ppmv)	<1.1	100	2.1
Ethylbenzene	EPA TO-3	(ppmv)	18	27	1.5
Xylenes, Total	EPA TO-3	(ppmv)	120	140	8.0
Surface Air Hydrocarbons			SPT3B [1]	SPT3A [2]	
TVH-jf	EPA TO-3	(ppmv)	0.49	1.5	
Benzene	EPA TO-3	(ppmv)	<0.002	<0.002	
Toluene	EPA TO-3	(ppmv)	<0.002	<0.002	
Ethylbenzene	EPA TO-3	(ppmv)	<0.002	<0.002	
Xylenes, Total	EPA TO-3	(ppmv)	0.005	0.009	

NOTES:

TRPH - Total recoverable petroleum hydrocarbons
TVH-jf - Total volatile hydrocarbons as jet fuel
TKN - Total Kjeldahl nitrogen
ppmv - Parts per million by volume
[1] - Collected prior to air injection
[2] - Collected during air injection

$CaCO_3$ - Calcium carbonate
mg/kg - milligrams per kilogram
NA - Not Analyzed

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Laboratory analysis of soil and soil-gas samples documented hydrocarbon contamination in all wells, although soil-gas readings were lower in VMP-3. The maximum contaminant levels in soil were: 3,370 mg/kg TRPH (VMP2-7), 0.4 mg/kg benzene (VMP2-7), 6.9 mg/kg toluene (VMP1-7), 24 mg/kg ethylbenzene (VMP2-7), and 150 mg/kg total xylenes (VMP2-7). The maximum contaminant levels in soil gas were: 29,000 ppmv TVH-jf, 32 ppmv benzene, 100 ppmv toluene, 27 ppmv ethylbenzene, and 140 ppmv total xylenes (all at VMP1-7).

2.6.5 Exceptions To Protocol Document Procedures

Protocol document procedures related to soil and soil-gas sampling were followed with no significant exceptions.

2.7 Building 2035

2.7.1 Soil Sample Field Analysis and Laboratory Analysis

Soil sample headspace OVA readings for Building 2035 were previously given in Table 1.9. Soil samples were collected and analyzed using the procedures described in Section 2.1. Samples were collected at VW-1, VMP-1, and VMP-2 from depths of 8, 7, and 8.5 feet bgs, respectively. The results of all analyses for Building 2035 samples are summarized in Table 2.5 and discussed below. The TRPH concentrations are also included on the geologic cross section (Figure 1.13).

2.7.2 Soil-Gas/Surface Air Sample Laboratory Analysis

Soil-gas samples were collected and analyzed using the procedures described in Section 2.2. Samples were collected from the vent well (VW-1) and from the screened intervals at 7.5 feet bgs in both VMP-1 and VMP-3. Results of these analyses are summarized in Table 2.5 and discussed below.

Additional surface air samples were collected for laboratory analysis before and during air injection to estimate potential emissions of TVH-jf and BTEX to the atmosphere resulting from air injection during the pilot test. Three samples were collected at a surface point (SPT) located 11 feet southwest of VW-1. One sample was collected prior to the start of air injection (sample SPT2A) and two samples were collected approximately 4 hours after the start of and during air injection (sample SPT2B plus a duplicate labeled SPT6B). The results of the surface air sample analyses are shown in Table 2.5 and discussed in Section 3.5.5.

2.7.3 Field QA/QC Results

A duplicate surface air sample (field duplicate) was collected from SPT2 during air injection as described in Section 2.7.2. The duplicate sample was labeled "SPT6B" so that the laboratory would not be able to identify the sample as a duplicate. Analytes were the same for the duplicate sample as for the regular sample (see Table 2.5). The two samples resulted in nearly identical measurements for volatile organics.

TABLE 2.5
SOIL, SOIL GAS, and SURFACE AIR ANALYTICAL RESULTS
Building 2035
Fairchild AFB, Washington

ANALYTE	METHOD	UNITS	SAMPLE LOCATION - DEPTH (WELL NUMBER AND FEET BELOW GROUND SURFACE)		
Soil Hydrocarbons:			VW1-8	VMP1-7 [1]	VMP2-8.5
TRPH	EPA 418.1	(mg/kg)	140	66	32
Benzene	SW8020	(mg/kg)	1.1	<0.00056	<0.0006
Toluene	SW8020	(mg/kg)	2.6	0.009	0.053
Ethylbenzene	SW8020	(mg/kg)	3.4	<0.00056	0.0013
Xylenes, Total	SW8020	(mg/kg)	4.7	0.0014	0.021
Soil Inorganics:			VW1-8	VMP1-7	VMP2-8.5
Iron	SW7380	(mg/kg dry wt.)	26,700	26,800	25,300
Total Alkalinity	SM403	(mg/kg as $CaCO_3$)	570	500	520
pH	SW9045	(units)	8.3	8.3	8.4
TKN	E351.2	(mg/kg dry wt.)	44	130	220
Total Phosphorus	E365.2	(mg/kg dry wt.)	210	270	430
Soil Physical Parameters:			VW1-8	VMP1-7	VMP2-8.5
Moisture Content	ASTM D2216	(% by wt.)	6.8	9.7	12
Gravel	ASTM D422	(% by wt.)	56.4	17.8	37.7
Sand	ASTM D422	(% by wt.)	47.2	50.6	34
Silt	ASTM D422	(% by wt.)	34.6	211.7	18.8
Clay	ASTM D422	(% by wt.)	12.9	9.9	9.6
Soil Gas Hydrocarbons:			VW1	VMP1-7.5	VMP3-7.5
TVH-jf	EPA TO-3	(ppmv)	17,000	14,000	14,000
Benzene	EPA TO-3	(ppmv)	<1.0	<1.0	<1.0
Toluene	EPA TO-3	(ppmv)	<1.0	<1.0	68
Ethylbenzene	EPA TO-3	(ppmv)	28	37	23
Xylenes, Total	EPA TO-3	(ppmv)	51	58	150
Surface Air Hydrocarbons			SPT2A [2]	SPT2B [3]	SPT2B [3,4]
TVH-jf	EPA TO-3	(ppmv)	1.60	0.30	0.23
Benzene	EPA TO-3	(ppmv)	<0.002	<0.002	<0.002
Toluene	EPA TO-3	(ppmv)	<0.002	0.005	0.006
Ethylbenzene	EPA TO-3	(ppmv)	0.002	<0.002	<0.002
Xylenes, Total	EPA TO-3	(ppmv)	0.018	0.011	0.01

NOTES:

TRPH - Total recoverable petroleum hydrocarbons
TVH-jf - Total volatile hydrocarbons as jet fuel
TKN - Total Kjeldahl nitrogen
ppmv - Parts per million by volume
[1] - Sample was analyzed one day past the hold time of 14 days
[2] - Collected prior to air injection
[3] - Collected during air injection
[4] - Duplicate labeled as 2035-SPT6B

$CaCO_3$ - Calcium carbonate
mg/kg - milligrams per kilogram
NA - Not Analyzed

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2.7.4 Subsurface Contamination

The extent of the hydrocarbon contamination at the site remains unknown. All boreholes drilled at the site encountered evidence of hydrocarbon contamination. OVA readings greater than 1,100 ppmv were measured in all boreholes. The highest OVA readings were generally recorded at the bottom of the borehole between 8 and 10 feet bgs, just above where groundwater was encountered. Fuel odors were noted in all borings and generally were stronger with depth. Possible free product was encountered at 9.5 to 10 feet bgs in VMP-1.

Laboratory analysis of soil and soil-gas samples documented hydrocarbon contamination in all wells, although soil contaminant levels were lower than at the other four sites. The maximum contaminant levels in soil were: 140 mg/kg TRPH, 1.1 mg/kg benzene, 2.6 mg/kg toluene, 3.4 mg/kg ethylbenzene, and 4.7 mg/kg total xylenes (all at VW1-8). The maximum contaminant levels in soil gas were: 17,000 ppmv TVH-jf (VW1), 68 ppmv toluene (VMP3-7.5), 37 ppmv ethylbenzene (VMP1-7.5), and 150 ppmv total xylenes (VMP3-7.5). No benzene was detected in soil-gas samples.

2.7.5 Exceptions To Protocol Document Procedures

Protocol document procedures related to soil and soil-gas sampling were followed with no significant exceptions.

2.8 Background Wells

2.8.1 Soil Sample Field Analysis and Laboratory Analysis

Soil sample headspace OVA readings for both background wells was previously given in Table 1.11. No PID readings were recorded due to equipment problems. Soil samples were collected and analyzed using the procedures described in Section 2.1, except that only soil nutrients (TKN and total phosphorus) and grain-size distribution were analyzed. Samples were collected at both VMP-B1 and VMP-B2 from a depth of 5 feet bgs. The results of all analyses for the background wells are summarized in Table 2.6.

2.8.2 Soil-Gas Sample Laboratory Analysis

No soil-gas samples were collected for laboratory analysis at the background wells. However, soil-gas samples were collected for field measurements during the pilot tests. These results are discussed in Section 3.6.

2.8.3 Field QA/QC Results

No Quality Assurance/Quality Control (QA/QC) soil or soil-gas samples (field duplicates) were collected during sampling activities at the background wells.

2.8.4 Subsurface Contamination

No evidence of subsurface contamination was encountered at either background VMP, indicating that the locations were acceptable for background well completion and measurements.

TABLE 2.6
SOIL ANALYTICAL RESULTS
Background Wells
Fairchild AFB, Washington

ANALYTE	METHOD	UNITS	SAMPLE LOCATION - DEPTH (WELL NUMBER AND FEET BGS)	
Soil Inorganics:			**VMPB1-5**	**VMPB2-5**
TKN	E351.2	(mg/kg dry wt.)	140	130
otal Phosporus	E365.2	(mg/kg dry wt.)	590	480
Soil Physical Parameters:			**VMPB1-5**	**VMPB2-5**
Gravel	ASTM D422	(% by wt.)	2.4	0.3
Sand	ASTM D422	(% by wt.)	58.8	43.0
Silt	ASTM D422	(% by wt.)	30.5	35.4
Clay	ASTM D422	(% by wt.)	8.3	21.2

NOTES:
TKN - Total Kjeldahl nitrogen
mg/kg - milligrams per kilogram

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2.8.5 Exceptions To Protocol Document Procedures

Protocol document procedures related to soil and soil-gas sampling were followed with no significant exceptions.

3.0 PILOT TEST RESULTS AND RECOMMENDATIONS

3.1 PS-2

3.1.1 Initial Soil-Gas Chemistry

Prior to initiating air injection, the VW and all VMPs were purged until oxygen levels had stabilized, and then initial oxygen, carbon dioxide, and TVH (total volatile hydrocarbon) concentrations were sampled using portable gas analyzers as described in the protocol document. Depleted oxygen levels and increased carbon dioxide levels were found in soil gas at the VW and at all VMP screened intervals, indicating soil contamination and natural biological activity at 4 to 10 feet bgs. The initial soil-gas chemistry and soil temperatures measured at PS-2 are summarized in Table 3.1. TVH for soil-gas samples (both field instrument measurements and laboratory analytical results) and TRPH and BTEX concentrations for soil samples are also provided to demonstrate the relationship between oxygen levels and the contaminated soils. Initial oxygen levels are also shown on the geologic cross-section for the site (Figure 1.5).

3.1.2 Air Permeability

An air permeability (AP) test was conducted on 5 October 1993 according to protocol document procedures. Air was injected into VW-1 for approximately 5.3 hours at a rate of 13 scfm with an average pressure at the well-head of 55 inches of water (in. H_2O). The dynamic pressure responses at the VMPs are shown on Figures D.1 through D.3 (see Appendix D).

Due to the quick pressure response and the short length of time required to achieve steady-state conditions, the steady-state response method was used to calculate air permeability values, as detailed in the protocol document. Steady-state pressure responses and calculated air permeabilities with depth are shown on Figure D.4 (see Appendix D). The shallow points were defined as those at approximately 4 feet bgs and the deep points were defined as those at approximately 7 feet bgs. Both shallow and deep points were located within the same lithologic zone at the site (see Figure 1.5).

Using the steady-state method, permeability values ranged from 4.2 to 4.3 darcys, typical for the silty sands at the site. The permeability values indicate that the site soils are sufficiently permeable to air for the bioventing technology.

3.1.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the VW is the primary design parameter for extended bioventing systems. The pilot test data determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 3.2 presents the change in soil-gas oxygen levels during the AP test. Increases in soil-gas oxygen levels occurred at VMP1-4 and VMP2-4, indicating successful oxygen transport at a radial distance of at least 20 ft, even for the relatively brief injection period. Based on measurable pressure response, which is an indicator of long-term oxygen transport, it is anticipated that the radius of oxygen influence for the extended pilot test

Table 3.1
INITIAL CONDITIONS
PS-2
Fairchild AFB, Washington

Well No.- depth	SOIL GAS O_2 (%)	CO_2 (%)	TVH-jf (ppmv)	TVH (ppmv)	SOIL TRPH (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Temp. (°F)
VW1-(5-10)	1.0	7.9	110,000	>10,000	250	0.7	0.5	7.2	47	
VMP1-4	2.5	4.8	78,000	>10,000	280	4.1	ND	21	120	62.8
VMP1-7.5	0.5	4.8		>10,000						63.3
VMP2-4	3.0	0.5		>10,000	980	0.14	ND	0.71	3.8	
VMP2-6.5	0.5	5.2		>10,000						
VMP3-4	2.0	6.5		>10,000						
VMP3-7	0.3	9.7	170,000	>10,000						

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
TVH : Total Volatile Hydrocarbons (THVA field instrument)

ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. O_2/CO_2 measurements by field instrumentation.
2. Soil sample at VW-1 taken at a depth of 7.5 feet bgs.
3. Benzene, Toluene, Ethylbenzene, and Total xylenes by EPA Method 8020.

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Table 3.2
INFLUENCE OF AIR INJECTION ON OXYGEN LEVELS
PS-2
Fairchild AFB, Washington

Well No.- depth	Distance from VW-1 (ft)	Air Permeability Test Inital O_2 (%)	Air Permeability Test Final O_2 (%)
VMP1-4	11.5	2.5	10.5
VMP1-7.5	11.5	0.5	0.7
VMP2-4	20	3.0	13.0
VMP2-6.5	20	0.5	0.7
VMP3-4	40	2.0	0.7
VMP3-7	40	0.3	0.3

NOTES

Air Permeability Test lasting 5.3 hours performed on October 5, 1993.

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will be at least 35 feet from VW-1 (see Figure D.4). The effective treatment radius for the extended pilot test will be better defined by monitoring the oxygen and contaminated soil-gas levels during the extended pilot test at the site.

3.1.4 *In Situ* Respiration Rates

An *in situ* respiration (ISR) test was conducted at PS-2 between 6 and 8 October 1993 according to protocol document procedures. Air (20.8 percent oxygen) was injected at a rate of approximately 1 scfm into four VMP screened intervals (VMP1-4, VMP2-4, VMP2-6.5, and VMP3-7) for 19 hours in order to oxygenate surrounding soils. After air injection was ceased, oxygen, carbon dioxide, and TVH levels in all VMP screened intervals (including those without air injection) were measured in soil gas for the following 31 hours. The results of the ISR test for PS-2 are presented on Figures E.1 to E.6 (see Appendix E).

Results from the ISR test indicate that all of the VMP screened intervals had hydrocarbon contamination and active microorganism populations. The oxygen-utilization rates measured at the site were moderate to average, ranging from approximately 0.15% per hour at VMP2-4 to approximately 1.4% per hour at VMP3-7. An oxygen-utilization rate was not calculated at VW-1 because the oxygen level measured at the start of the ISR test was too low to accurately measure a rate.

The air injected into the VMPs during the ISR test was a 2.5-percent helium mixture in air. The helium is used both as a tracer gas and to evaluate the effectiveness of the bentonite seals in the VW and VMPs. No appreciable loss of helium occurred at any VMPs where helium was injected between the end of injection and the final ISR readings taken after 31 hours of monitoring. Therefore, most of the oxygen loss observed during the ISR test was a result of bacterial respiration and not a result of either faulty well construction or overpurging of the VMPs during sampling.

Helium was also monitored at VW-1 and at VMPs where air injection did not occur. Detection of helium at these points provides some evidence that significant volumes of soil were aerated by the 1 scfm pumps and consistent helium levels at these points over time indicates that decreasing oxygen levels in extracted soil-gas are due to respiration.

Based on the measured oxygen-utilization rates and the laboratory analyses presented in Section 2.3, an estimated 510 to 5,100 mg of fuel per kg of soil can be biodegraded each year at this site. The lower estimate reflects the slower oxygen-utilization rate measured at VMP2-4, while the higher estimate reflects the high oxygen-utilization rate and lower moisture content that was measured at VMP3-4. The biodegradation rate estimates are based on calculated air-filled porosities and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Methods of calculation followed the procedures in the protocol document and are detailed in Appendix F.

Additional respiration testing at 6 months and one year following installation of the extended (one-year) pilot test system, and soil sampling one year following installation, will better define the long-term biodegradation rates. Table 3.3 summarizes the data from the initial pilot test at PS-2.

Table 3.3
PILOT TEST DATA SUMMARY
PS-2
Fairchild AFB, Washington

		Laboratory Analytical Results		Air Permeability Test				*In Situ* Respiration Test					Calculated Biodegradation Rate
				Initial Soil Gas		Final Soil Gas	Air Perm.	Initial Soil Gas		Final Soil Gas		O_2 Util. Rate	
WELL No.-DEPTH	Soil Type	TRPH (mg/kg)	TVH-jf (ppmv)	O_2 (%)	CO_2 (%)	O_2 (%)	k (darcy)	O_2 (%)	He (%)	O_2 (%)	He (%)	k_o (%/hr)	K_b (mg fuel/kg soil/yr)
VW1-(5-10)	SAND/ silty SAND	250	110,000	1.0	7.9	---	---	6.5	2.0	2.8	1.4	---	---
VMP1-4 •	silty SAND	280	78,000	2.5	4.8	10.5	4.3	20.8	1.9	8.8	1.4	0.34	1,600
VMP1-7.5	SILT/ CLAY			0.5	4.8	0.7	4.2	10.8	1.3	3.0	1.0	0.48	1,100
VMP2-4 •	silty SAND	980		3.0	0.5	13.0	4.3	20.5	2.0	15.8	1.0	0.15	510
VMP2-6.5 •	fine SAND/ SILT			0.5	5.2	0.7	4.2	20.8	2.1	10.3	1.5	0.32	670
VMP3-4	SAND/ SILT			2.0	6.5	0.7	4.3	19.5	2.1	3.0	1.2	1.1	5,100
VMP3-7 •	silty SAND		170,000	0.3	9.7	0.3	4.2	19.8	2.6	0.5	2.9	1.4	2,200

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
• : VMP used for air injection during ISR test.

ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. VW-1 soil sample collected from 7.5 ft bgs.
2. Air Permeability Test conducted for 5.3 hrs at air injection rate of 13 scfm.
3. *In Situ* Respiration Test: air injection at selected VMPs for 19 hrs at 1.1 scfm; O_2/CO_2/TVH measurements taken for 31 hrs following injection.
4. Soil Temperature: 62.8 °F at VMP1-4; 63.3 °F at VMP1-7.5.

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3.2 PS-1A

3.2.1 Initial Soil-Gas Chemistry

Prior to initiating air injection, the VW and all VMPs were purged until oxygen levels had stabilized, and then initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers as described in the protocol document. Depleted oxygen levels and increased carbon dioxide levels were found in soil gas at the VW and at all VMP screened intervals, indicating soil contamination and natural biological activity at 3 to 8 feet bgs. The initial soil-gas chemistry and soil temperatures measured at PS-1A are summarized in Table 3.4. TVH for soil-gas samples (both field instrument measurements and laboratory analytical results) and TRPH and BTEX concentrations for soil samples are also provided to demonstrate the relationship between oxygen levels and the contaminated soils. Initial oxygen levels are also shown on the geologic cross-section for the site (Figure 1.7).

3.2.2 Air Permeability

An AP test was conducted between 27 and 27 October 1993 according to protocol document procedures. Air was injected into VW-1 for approximately 24 hours at a rate of 16 scfm with an average pressure at the well-head of 14 in. H_2O. The dynamic pressure responses at the VMPs are shown on Figures D.5 through D.7.

Due to the quick pressure response and the short length of time required to achieve steady-state conditions, the steady-state response method was used to calculate air permeability values, as detailed in the protocol document. Steady-state pressure responses and calculated air permeabilities with depth are shown on Figure D.8. The shallow points were defined as those at approximately 3 feet bgs and the deep points were defined as those at approximately 5.5 feet bgs.

Using the steady-state method, the permeability value for site soils is approximately 29 darcys, typical for the sands and silty sands which are predominant at the site. However, because the VMP screens were located in varying lithologic zones at the site (see Figure 1.7), the permeability value represents an average of overall site conditions. The calculated permeability value indicates that the site soils are sufficiently permeable to air for the bioventing technology.

3.2.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the VW is the primary design parameter for extended bioventing systems. The pilot test data determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 3.5 presents the change in soil-gas oxygen levels during the AP test. Increases in soil-gas oxygen levels occurred at all VMPs and at most depths, indicating successful oxygen transport at a radial distance of at least 45 ft, in close agreement with the radius of influence calculated from the AP test data (see Figure D.8). The effective treatment radius for the extended pilot test will be better defined by monitoring the oxygen and contaminated soil-gas levels during the extended pilot test at the site.

Table 3.4
INITIAL CONDITIONS
PS-1A
Fairchild AFB, Washington

	SOIL GAS				SOIL					
Well No.- depth	O_2 (%)	CO_2 (%)	TVH-jf (ppmv)	TVH (ppmv)	TRPH (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Temp. (°F)
VW1-(4-8)	2.5	11.2	23,000/25,000	>10,000	390/5,660	ND/5.6	11/91	6.7/56	44/340	
VMP1-4	0.0	11.7		>10,000						53.1
VMP1-6	0.0	12.3	26,000	>10,000						52.0
VMP2-3	1.5	10.0		>10,000	1,940	ND	11	ND	49	
VMP2-5.5	0.0	12.7		>10,000						
VMP3-3	0.0	10.7		>10,000						
VMP3-5.5	0.0	12.0	11,000	>10,000	140	ND	8	4	22	

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
TVH : Total Volatile Hydrocarbons (THVA field instrument)

ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. O_2/CO_2 measurements by field instrumentation.
2. Soil samples at VW-1 taken at a depth of 6 and 7 feet bgs.
3. Benzene, Toluene, Ethylbenzene, and Total xylenes by EPA Method 8020.

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Table 3.5
INFLUENCE OF AIR INJECTION ON OXYGEN LEVELS
PS-1A
Fairchild AFB, Washington

Well No.- depth	Distance from VW-1 (ft)	Air Permeability Test Initial O_2 (%)	Air Permeability Test Final O_2 (%)
VMP1-4	10	0.0	19.8
VMP1-6	10	0.0	19.5
VMP2-3	25	1.5	4.8
VMP2-5.5	25	0.0	4.0
VMP3-3	45	0.0	1.5
VMP3-5.5	45	0.0	11.8

NOTES

Air Permeability Test lasting 24 hours performed on October 27-28, 1993.

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3.2.4 *In Situ* Respiration Rates

An ISR test was conducted at PS-1A between 27 and 29 October 1993 according to protocol document procedures. Air (20.8 percent oxygen) was injected at a rate of approximately 1 scfm into three VMP screened intervals (VMP1-6, VMP2-3, and VMP3-5.5) for 22 hours in order to oxygenate surrounding soils. After air injection was ceased, oxygen, carbon dioxide, and TVH levels in all VMP screened intervals (including those without air injection) were measured in soil gas for the following 24 hours. The results of the ISR test for PS-1A are presented on Figures E.7 to E.12.

Results from the ISR test indicate that the VW and most of the VMP screened intervals had hydrocarbon contamination and active microorganism populations. The oxygen-utilization rates measured at the site were moderate to high, ranging from approximately 0.37% per hour at VW-1 to approximately 1.8% per hour at VMP2-5.5. An oxygen-utilization rate was not calculated at VMP3-3 because the point was not aerated during the test.

The air injected into the VMPs during the ISR test was a 3-percent helium mixture in air. The helium is used both as a tracer gas and to evaluate the effectiveness of the bentonite seals in the VW and VMPs. No appreciable loss of helium occurred at any VMPs where helium was injected between the end of injection and the final ISR readings taken after 24 hours of monitoring. Therefore, most of the oxygen loss observed during the ISR test was a result of bacterial respiration and not a result of either faulty well construction or overpurging of the VMPs during sampling.

Helium was also monitored at VW-1 and at VMPs where air injection did not occur. Detection of helium at these points provides some evidence that significant volumes of soil were aerated by the 1 scfm pumps and consistent helium levels at these points over time indicates that decreasing oxygen levels in extracted soil-gas are due to respiration.

Based on the measured oxygen-utilization rates and the laboratory analyses presented in Section 2.4, an estimated 1,000 to 8,300 mg of fuel per kg of soil can be biodegraded each year at this site. The lower estimate reflects the slower oxygen-utilization rate measured at VW-1, while the higher estimate reflects the high oxygen-utilization rate that was measured at VMP2-5.5. The biodegradation rates are also highly dependent on soil moisture content, which varied from 6.8% to 13% for site soils. The biodegradation rate estimates are based on calculated air-filled porosities and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Methods of calculation followed the procedures in the protocol document and are detailed in Appendix F.

Additional respiration testing at 6 months and one year following installation of the extended (one-year) pilot test system, and soil sampling one year following installation, will better define the long-term biodegradation rates. Table 3.6 summarizes the data from the initial pilot test at PS-1A.

Table 3.6
PILOT TEST DATA SUMMARY
PS-1A
Fairchild AFB, Washington

WELL No.-DEPTH	Soil Type	Laboratory Analytical Results TRPH (mg/kg)	TVH-jf (ppmv)	Air Permeability Test Initial Soil Gas O_2 (%)	CO_2 (%)	Final Soil Gas O_2 (%)	Air Perm. k (darcy)	*In Situ* Respiration Test Initial Soil Gas O_2 (%)	He (%)	Final Soil Gas O_2 (%)	He (%)	O_2 Util. Rate k_o (%/hr)	Calculated Biodegradation Rate K_b (mg fuel/kg soil/yr)
VW1-(4-8)	SAND/ silty SAND	390/5,660	23,000/25,000	2.5	11.2	20.0	---	11.0	2.0	2.0	1.3	0.37	1,000
VMP1-4	silty SAND			0.0	11.7	19.8	29	20.2	2.6	1.2	2.6	0.79	2,500
VMP1-6 •	SAND		26,000	0.0	12.3	19.5	29	20.0	3.1	0.5	2.8	0.80	3,700
VMP2-3 •	silty SAND	1,940		1.5	10.0	4.8	29	19.2	2.6	4.0	1.5	1.4	5,900
VMP2-5.5	SAND			0.0	12.7	4.0	29	18.0	2.8	0.0	2.5	1.8	8,300
VMP3-3	GRAVEL			0.0	10.7	1.5	29	0.0	0.8	0.0	0.6	---	---
VMP3-5.5 •	clayey SILT	140	11,000	0.0	12.0	11.8	29	19.0	2.4	1.2	1.1	0.71	3,100

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
• : VMP used for air injection during ISR test.

ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. VW-1 soil samples collected from 6 and 7 ft bgs
2. Air Permeability Test conducted for 24 hrs at air injection rate of 16 scfm.
3. *In Situ* Respiration Test: air injection at selected VMPs for 22 hrs at 1.1 scfm; O_2 /CO_2 /TVH measurements taken for 24 hrs following injection.
4 Soil Temperature: 53.1 °F at VMP1-4; 52.0 °F at VMP1-6.

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3.3 PS-1B

3.3.1 Initial Soil-Gas Chemistry

Prior to initiating air injection, the VW and all VMPs were purged until oxygen levels had stabilized, and then initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers as described in the protocol document. Depleted oxygen levels and increased carbon dioxide levels were found in soil gas at the VW and at all VMP screened intervals, indicating soil contamination and natural biological activity at 3 to 9 feet bgs. The initial soil-gas chemistry and soil temperatures measured at PS-1B are summarized in Table 3.7. TVH for soil-gas samples (both field instrument measurements and laboratory analytical results) and TRPH and BTEX concentrations for soil samples are also provided to demonstrate the relationship between oxygen levels and the contaminated soils. Initial oxygen levels are also shown on the geologic cross-section for the site (Figure 1.9).

3.3.2 Air Permeability

An AP test was conducted on 2 November 1993 according to protocol document procedures. Air was injected into VW-1 for approximately 5.8 hours at a flow rate of 15 scfm with an average pressure at the well-head of 28 in. H_2O. The dynamic pressure responses at the VMPs are shown on Figures D.9 through D.11.

Due to the quick pressure response and the short length of time required to achieve steady-state conditions at most VMPs, the steady-state response method was used to calculate air permeability values, as detailed in the protocol document. Steady-state pressure responses and calculated air permeabilities with depth are shown on Figure D.12. The shallow points were defined as those at approximately 3 feet bgs and the deep points were defined as those at approximately 5 feet bgs.

Using the steady-state method, the permeability value for site soils is approximately 12 darcys, typical for the silty sands which are predominant at the site (see Figure 1.9). The dynamic response method was able to be used for calculating the permeability at VMP1-5 (see Figure D.9); the resultant value of 18 darcys compares favorably to the average value calculated from the steady-state method. The calculated permeability values indicate that the site soils are sufficiently permeable to air for the bioventing technology.

3.3.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the VW is the primary design parameter for extended bioventing systems. The pilot test data determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 3.8 presents the change in soil-gas oxygen levels during the AP test. Increases in soil-gas oxygen levels occurred at VMP-1, indicating successful oxygen transport at a radial distance of at least 10 ft, even for the relatively brief injection period. Decreases in soil-gas oxygen levels occurred at VMP-2, probably the result of displacement of oxygen-depleted soil gas during the test. Based on measurable pressure response and

Table 3.7
INITIAL CONDITIONS
PS-1B
Fairchild AFB, Washington

Well No.- depth	SOIL GAS O$_2$ (%)	CO$_2$ (%)	TVH-jf (ppmv)	TVH (ppmv)	SOIL TRPH (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Temp. (°F)
VW1-(4.5-8.8)	4.5	3.4	20,000	>10,000	190	0.01	0.023	0.019	0.26	
VMP1-3.5	3.8	5.0		>10,000						48.6
VMP1-6	0.0	6.5	25,000/24,000	>10,000	ND	ND	62	49	190	47.0
VMP2-3	17.5	2.5		>10,000						
VMP2-5.5	16.0	3.2		>10,000	1,580	ND	10	24	130	
VMP3-2.5	1.0	9.0		>10,000						
VMP3-5	0.0	9.5	25,000	>10,000						

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
TVH : Total Volatile Hydrocarbons (THVA field instrument)
ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. O_2/CO_2 measurements by field instrumentation.
2. Soil sample at VW-1 taken at a depth of 6 feet bgs.
3. Benzene, Toluene, Ethylbenzene, and Total xylenes by EPA Method 8020.

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Table 3.8
INFLUENCE OF AIR INJECTION ON OXYGEN LEVELS
PS-1B
Fairchild AFB, Washington

Well No.- depth	Distance from VW-1 (ft)	Air Permeability Test Initial O_2 (%)	Air Permeability Test Final O_2 (%)
VMP1-3.5	10	3.8	9.5
VMP1-6	10	0.0	20.0
VMP2-3	23	17.5	10.0
VMP2-5.5	23	16.0	11.0
VMP3-2.5	40	1.0	0.0
VMP3-5	40	0.0	0.5

LEGEND

Air Permeability Test lasting 5.8 hours performed on November 2, 1993.

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changes in soil-gas oxygen levels during the AP test, which are indicators of long-term oxygen transport, it is anticipated that the radius of oxygen influence for the extended pilot test will be 30 to 40 feet from VW-1 (see Figure D.12). The effective treatment radius for the extended pilot test will be better defined by monitoring the oxygen and contaminated soil-gas levels during the extended pilot test at the site.

3.3.4 *In Situ* Respiration Rates

An ISR test was conducted at PS-1B between 3 and 5 November 1993 according to protocol document procedures. Air (20.8 percent oxygen) was injected at a flow rate of approximately 1 scfm into three VMP screened intervals (VMP1-6, VMP2-5.5, and VMP3-5) for 24 hours in order to oxygenate surrounding soils. After air injection was ceased, oxygen, carbon dioxide, and TVH levels in all VMP screened intervals (including those without air injection) were measured in soil gas for the following 26 hours. The results of the ISR test for PS-1B are presented on Figures E.13 to E.16.

Results from the ISR test indicate that most of the VMP screened intervals had hydrocarbon contamination and active microorganism populations. The oxygen-utilization rates measured at the site were varied, ranging from approximately 0.073% per hour at VMP2-3 to approximately 1.1% per hour at VMP1-6. Oxygen-utilization rates were not calculated at VW-1, VMP1-3, and VMP3-2.5 because these points were not aerated during the test.

The air injected into the VMPs during the ISR test was a 4-percent helium mixture in air. The helium is used both as a tracer gas and to evaluate the effectiveness of the bentonite seals in the VW and VMPs. With the exception of VMP2-5.5, no appreciable loss of helium occurred at any VMPs where helium was injected between the end of injection and the final ISR readings taken after 26 hours of monitoring. Therefore, most of the oxygen loss observed during the ISR test was a result of bacterial respiration and not a result of either faulty well construction or overpurging of the VMPs during sampling.

The loss of helium over the duration of the test in VMP2-3 and VMP2-5.5 (see Figure E.15 and Figure E.16) is higher than expected and may be due to a preferential flow path in the subsurface or a poor bentonite seal. Therefore, the oxygen-utilization and biodegradation rates measured at these points may be inaccurate.

Helium was also monitored at VW-1 and at VMPs where air injection did not occur. Detection of helium at these points provides some evidence that significant volumes of soil were aerated by the 1 scfm pumps and consistent helium levels at these points over time indicates that decreasing oxygen levels in extracted soil-gas are due to respiration.

Based on the measured oxygen-utilization rates and the laboratory analyses presented in Section 2.5, an estimated 160 to 2,200 mg of fuel per kg of soil can be biodegraded each year at this site. The lower estimate reflects the slower oxygen-utilization rate measured at VMP2-3, while the higher estimate reflects the high oxygen-utilization rates measured at VMP1-6 and VMP3-5. The biodegradation rate estimates are based on

calculated air-filled porosities and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Methods of calculation followed the procedures in the protocol document and are detailed in Appendix F.

Additional respiration testing at 6 months and one year following installation of the extended (one-year) pilot test system, and soil sampling one year following installation, will better define the long-term biodegradation rates. Table 3.9 summarizes the data from the initial pilot test at PS-1B.

3.4 Building 2034

3.4.1 Initial Soil-Gas Chemistry

Prior to initiating air injection, the VW and all VMPs were purged until oxygen levels had stabilized, and then initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers as described in the protocol document. Depleted oxygen levels and increased carbon dioxide levels were found in soil gas at the VW and at all VMP screened intervals, indicating soil contamination and natural biological activity at 4 to 10 feet bgs. The initial soil-gas chemistry and soil temperatures measured at Building 2034 are summarized in Table 3.10. TVH for soil-gas samples (both field instrument measurements and laboratory analytical results) and TRPH and BTEX concentrations for soil samples are also provided to demonstrate the relationship between oxygen levels and the contaminated soils. Initial oxygen levels are also shown on the geologic cross-section for the site (Figure 1.11).

3.4.2 Air Permeability

An AP test was conducted on 13 October 1993 according to protocol document procedures. Air was injected into VW-1 for approximately 5 hours at a flow rate of 13 scfm with an average pressure at the well-head of 28 in. H_2O. The dynamic pressure responses at the VMPs are shown on Figures D.13 through D.15.

Due to the very quick pressure response and the short length of time required to achieve steady-state conditions at the VMPs, the steady-state response method was used to calculate air permeability values, as detailed in the protocol document. Steady-state pressure responses and calculated air permeabilities with depth are shown on Figure D.16. The shallow points were defined as those at between 4 and 5 feet bgs and the deep points were defined as those at between 7 and 8.5 feet bgs.

Using the steady-state method, the permeability value for site soils is approximately 9 darcys, typical for the silty sands which are predominant at the site (see Figure 1.11). The calculated permeability value indicates that the site soils are sufficiently permeable to air for the bioventing technology.

3.4.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the VW is the primary design parameter for extended bioventing systems. The pilot test data determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 3.9
PILOT TEST DATA SUMMARY
PS-1B
Fairchild AFB, Washington

WELL No.-DEPTH	Soil Type	Laboratory Analytical Results: TRPH (mg/kg)	Laboratory Analytical Results: TVH-jf (ppmv)	Air Permeability Test: Initial Soil Gas O_2 (%)	Air Permeability Test: Initial Soil Gas CO_2 (%)	Air Permeability Test: Final Soil Gas O_2 (%)	Air Permeability Test: Air Perm. k (darcy)	*In Situ* Respiration Test: Initial Soil Gas O_2 (%)	*In Situ* Respiration Test: Initial Soil Gas He (%)	*In Situ* Respiration Test: Final Soil Gas O_2 (%)	*In Situ* Respiration Test: Final Soil Gas He (%)	*In Situ* Respiration Test: O_2 Util. Rate k_o (%/hr)	Calculated Biodegradation Rate K_b (mg fuel/kg soil/yr)
VW1-(4.5-8.8)	SAND/ silty SAND	190	20,000	4.5	3.4	---	---	4.0	3.0	2.2	1.9	---	---
VMP1-3.5	silty SAND			3.8	5.0	9.5	12	5.5	1.7	5.0	1.9	---	---
VMP1-6 •	SAND	ND	25,000/24,000	0.0	6.5	20.0	18	19.8	3.0	1.5	4.2	1.1	2,100
VMP2-3	silty SAND			17.5	2.5	10.0	12	20.5	1.7	18.6	0.20	0.073	160
VMP2-5.5 •	SAND	1,580		16.0	3.2	11.0	12	20.5	1.3	16.2	0.47	0.16	630
VMP3-2.5	silty SAND			1.0	9.0	0.0	12	1.5	3.3	1.2	1.4	---	---
VMP3-5 •	silty SAND		25,000	0.0	9.5	0.5	12	19.3	3.1	1.3	4.0	1.0	2,200

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
• : VMP used for air injection during ISR test.

ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. VW-1 soil sample collected from 6 ft bgs.
2. Air Permeability Test conducted for 5.8 hrs at air injection rate of 15 scfm.
3. *In Situ* Respiration Test: air injection at selected VMPs for 24 hrs at 1.1 scfm; O_2 /CO_2 /TVH measurements taken for 26 hrs following injection.
4. Soil Temperature: 48.6 °F at VMP1-3; 47.0 °F at VMP1-5.

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Table 3.10
INITIAL CONDITIONS
Building 2034
Fairchild AFB, Washington

	SOIL GAS				SOIL					
	O_2	CO_2	TVH-jf	TVH	TRPH	Benzene	Toluene	Ethylbenzene	Total Xylenes	Temp.
Well No.- depth	(%)	(%)	(ppmv)	(ppmv)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(°F)
VW1-(5-10)	4.2	8.1	23,000	>10,000	1,330	0.075	0.41	0.68	5.2	
VMP1-4	5.4	7.6		>10,000						53.4
VMP1-7	1.0	10.2	29,000	>10,000	1,160	0.28	6.9	13	77	57.4
VMP2-4	8.0	7.5		1,100						
VMP2-7	1.9	10.6		>10,000	3,370	0.4	3	24	150	
VMP3-5	11.4	5.2		280						
VMP3-8.5	1.4	12.5	570	150						

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
TVH : Total Volatile Hydrocarbons (THVA field instrument)

ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. O_2/CO_2 measurements by field instrumentation.
2. Soil sample at VW-1 taken at a depth of 5 feet bgs.
3. Benzene, Toluene, Ethylbenzene, and Total xylenes by EPA Method 8020.

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Table 3.11 presents the change in soil-gas oxygen levels during the AP test. Increases in soil-gas oxygen levels occurred at most of the VMP screens, indicating successful oxygen transport at a radial distance of at least 33 ft, even for the relatively brief injection period. This measured radius of oxygen influence is in close agreement with the radius of pressure influence calculated from the AP test data (see Figure D.16). Based on measurable pressure response and changes in soil-gas oxygen levels during the AP test, which are indicators of long-term oxygen transport, it is anticipated that the radius of oxygen influence for the extended pilot test will be approximately 35 feet from VW-1. The effective treatment radius for the extended pilot test will be better defined by monitoring the oxygen and contaminated soil-gas levels during the extended pilot test at the site.

3.4.4 *In Situ* Respiration Rates

An ISR test was conducted at Building 2034 between 14 and 16 October 1993 according to protocol document procedures. Air (20.8 percent oxygen) was injected at a rate of approximately 1 scfm into four VMP screened intervals (VMP1-4, VMP1-7.5, VMP2-7, and VMP3-8.5) for 21 hours in order to oxygenate surrounding soils. After air injection was ceased, oxygen, carbon dioxide, and TVH levels in all VMP screened intervals (including those without air injection) were measured in soil gas for the following 29.5 hours. The results of the ISR test for Building 2034 are presented on Figures E.17 to E.23.

Results from the ISR test indicate that the VW and all of the VMP screened intervals had hydrocarbon contamination and active microorganism populations. The oxygen-utilization rates measured at the site were varied, ranging from approximately 0.12% per hour at VMP3-5 to approximately 1.1% per hour at VMP2-7.

The air injected into the VMPs during the ISR test was a 2.7-percent helium mixture in air. The helium is used both as a tracer gas and to evaluate the effectiveness of the bentonite seals in the VW and VMPs. No appreciable loss of helium occurred at any VMPs where helium was injected between the end of injection and the final ISR readings taken after 29.5 hours of monitoring. Therefore, most of the oxygen loss observed during the ISR test was a result of bacterial respiration and not a result of either faulty well construction or overpurging of the VMPs during sampling.

Helium was also monitored at VW-1 and at VMPs where air injection did not occur. Detection of helium at these points provides some evidence that significant volumes of soil were aerated by the 1 scfm pumps and consistent helium levels at these points over time indicates that decreasing oxygen levels in extracted soil-gas are due to respiration.

Based on the measured oxygen-utilization rates and the laboratory analyses presented in Section 2.6, an estimated 380 to 2,900 mg of fuel per kg of soil can be biodegraded each year at this site. The lower estimate reflects the slower oxygen-utilization rate measured at VMP3-5, while the higher estimate reflects the high oxygen-utilization rate and lower moisture content measured at VMP1-4. The biodegradation rate estimates are

Table 3.11
INFLUENCE OF AIR INJECTION ON OXYGEN LEVELS
Building 2034
Fairchild AFB, Washington

Well No.- depth	Distance from VW-1 (ft)	Air Permeability Test Inital O_2 (%)	Air Permeability Test Final O_2 (%)
VMP1-4	10	5.4	16.2
VMP1-7	10	1.0	18.2
VMP2-4	20	8.0	9.5
VMP2-7	20	1.9	10.0
VMP3-5	32.5	11.4	13.0
VMP3-8.5	32.5	1.4	0.2

NOTES
Air Permeability Test lasting 5 hours performed on October 13, 1993.

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based on calculated air-filled porosities and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Methods of calculation followed the procedures in the protocol document and are detailed in Appendix F.

Additional respiration testing at 6 months and one year following installation of the extended (one-year) pilot test system, and soil sampling one year following installation, will better define the long-term biodegradation rates. Table 3.12 summarizes the data from the initial pilot test at Building 2034.

3.4.5 Potential Air Emissions

Air samples were taken at the ground surface at the Building 2034 site before and during air injection in order to evaluate the potential for discharge of petroleum hydrocarbons to the atmosphere resulting from subsurface air injection. The results indicate that no significant increase in either TVH or BTEX levels above those found prior to air injection at the site are expected to occur during the extended (one-year) pilot test.

Five surface measurement points were located radially around the injection well (VW-1) and at distances expected to be under the influence of air injection. Three of the surface measurement points were arranged around VW-1 roughly 120 degrees apart and located at a distance of 12 feet from VW-1. The remaining two measurement points were spaced at 24 and 36 feet from VW-1 in order to characterize the radial extent of any emissions. The air injection flow rate was approximately 15 scfm. Samples were collected as described in Section 2.2.

Results from the THVA were recorded in the field notebook and are shown in Table 3.13. In order to determine the TVH-jf and BTEX content of potential emissions, two surface air samples were collected for laboratory analysis, one prior to air injection and one during air injection (4 hours after initiation of injection) at the same location (SPT3), located 12 feet from VW-1. Results of the laboratory analysis for the two samples were summarized in Table 2.4.

Using very conservative assumptions that the hydrocarbon emission rates do not decrease over time and that the emission rates for the surface points nearest the injection well apply throughout the entire radius of influence, the potential total hydrocarbon emissions are estimated at 0.017 lbs/hr (150 lbs/yr). Because no benzene emissions were detected, potential benzene emissions are expected to be negligible.

These levels are significantly below the requirements set forth by the Washington Department of Ecology for small quantity emissions in WAC 173-460-080 for benzene (Class A pollutant) and total hydrocarbons (Class B pollutant). The long-term potential for air emissions during the extended (one-year) pilot test is also very low since the initial air injection probably displaced the highest concentrations of volatiles from the soil and the concentrations typically decrease with continued air injection. In addition, any accumulated petroleum hydrocarbon vapors in the pore space will be biodegraded as they move horizontally through the soil.

Table 3.12
PILOT TEST DATA SUMMARY
Building 2034
Fairchild AFB, Washington

				Air Permeability Test				*In Situ* Respiration Test					Calculated Biodegradation Rate
	Soil Type	Laboratory Analytical Results		Initial Soil Gas		Final Soil Gas	Air Perm.	Initial Soil Gas		Final Soil Gas		O_2 Util. Rate	
WELL No.-DEPTH		TRPH (mg/kg)	TVH-jf (ppmv)	O_2 (%)	CO_2 (%)	O_2 (%)	k (darcy)	O_2 (%)	He (%)	O_2 (%)	He (%)	k_o (%/hr)	K_b (mg fuel/kg soil/yr)
VW1-(5-10)	silty SAND	1,330	23,000	4.2	8.1	---	---	16.2	2.4	2.0	2.4	0.76	2,500
VMP1-4 •	silty SAND			5.4	7.6	16.2	8.6	20.5	2.5	5.1	2.2	0.93	2,900
VMP1-7 •	silty SAND	1,160	29,000	1.0	10.2	18.2	8.7	20.8	2.6	2.8	2.9	0.70	2,700
VMP2-4	silty SAND			8.0	7.5	9.5	8.6	20.5	2.5	6.9	1.9	0.50	1,600
VMP2-7 •	silty SAND	3,370		1.9	10.6	10.0	8.7	20.4	2.6	2.8	2.6	1.1	2,100
VMP3-5	silty SAND			11.4	5.2	13.0	8.6	20.0	1.0	16.1	1.0	0.12	380
VMP3-8.5 •	gravelly CLAY		570	1.4	12.5	0.2	8.7	20.5	2.6	6.9	1.9	0.46	2,000

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
• : VMP used for air injection during ISR test.

ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. VW-1 soil sample collected from 5 ft bgs.
2. Air Permeability Test conducted for 5.0 hrs at air injection rate of 12 scfm.
3. *In Situ* Respiration Test: air injection at selected VMPs for 21 hrs at 1.1 scfm; O_2 /CO_2 /TVH measurements taken for 29.5 hrs following injection.
4. Soil Temperature: 53.4 °F at VMP1-4; 57.4 °F at VMP1-7.

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Table 3.13
SURFACE AIR EMISSIONS
Building 2034
Fairchild AFB, Washington

Location	Distance from VW-1 (ft)	Prior to Air Injection	During Air Injection [1]
		TVH concentrations in ppmv	
SPT1	12	0	0
SPT2	12	4	6
SPT3	12	0	13
SPT4	24	2	31
SPT5	36	0	4

LEGEND

TVH :Total Volatile Hydrocarbons (THVA field instrument)
ppmv :parts per million by volume
[1] :Sample collection begun approximately 5 hours after start of injection

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3.5 Building 2035

3.5.1 Initial Soil-Gas Chemistry

Prior to initiating air injection, the VW and all VMPs were purged until oxygen levels had stabilized, and then initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers as described in the protocol document. Depleted oxygen levels and increased carbon dioxide levels were found in soil gas at the VW and at all VMP screened intervals, indicating soil contamination and natural biological activity at 5 to 10 feet bgs. The initial soil-gas chemistry and soil temperatures measured at Building 2035 are summarized in Table 3.14. TVH for soil-gas samples (both field instrument measurements and laboratory analytical results) and TRPH and BTEX concentrations for soil samples are also provided to demonstrate the relationship between oxygen levels and the contaminated soils. Initial oxygen levels are also shown on the geologic cross-section for the site (Figure 1.13).

3.5.2 Air Permeability

An AP test was conducted between 19 and 20 October 1993 according to protocol document procedures. Air was injected into VW-1 for approximately 20 hours at a flow rate of 18 scfm with an average pressure at the well-head of 19 in. H_2O. The dynamic pressure responses at the VMPs are shown on Figures D.17 through D.19.

The magnitude of the pressure response at the site was low — the maximum response in VMP-1, the closest monitoring point, was only 0.25 in. H_2O. Due to the quick pressure response and the short length of time required to achieve steady-state conditions at the VMPs, the steady-state response method was used to calculate air permeability values, as detailed in the protocol document. Steady-state pressure responses and calculated air permeabilities with depth are shown on Figure D.20. The shallow points were defined as those at 5 feet bgs and the deep points were defined as those at 7.5 feet bgs.

Using the steady-state method, the permeability values for site soils ranged from 17 and 19 darcys, typical for the silty sands which are predominant at the site (see Figure 1.13). The calculated permeability value indicates that the site soils are sufficiently permeable to air for the bioventing technology.

3.5.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the VW is the primary design parameter for extended bioventing systems. The pilot test data determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 3.15 presents the change in soil-gas oxygen levels during the AP test. Only very minor changes in soil-gas oxygen levels occurred at the VMP screens at this site over the 24-hour injection period. Although disappointing, this result was consistent with the very low pressure response noted during the AP test (see Section 3.5.2). The low response may be due to the proximity of the UST complex to the VW and the VMPs and/or the fill material surrounding the USTs, which may be providing a preferential flow

Table 3.14
INITIAL CONDITIONS
Building 2035
Fairchild AFB, Washington

	SOIL GAS				SOIL					
Well No.- depth	O_2 (%)	CO_2 (%)	TVH-jf (ppmv)	TVH (ppmv)	TRPH (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Total Xylenes (mg/kg)	Temp. (°F)
VW-(5-10)	5.5	9.5	17,000	>10,000	140	1.1	2.6	3.4	4.7	
VMP1-5	10.2	4.9		2,800						57.8
VMP1-7.5	10.5	5.1	14,000	>10,000	66	ND	0.0090	ND	0.0014	58.2
VMP2-5	6.9	9.0		880						
VMP2-7.5	0.0	10.7		6,600	32	ND	0.053	0.0013	0.021	
VMP3-5	6.5	9.0		750						
VMP3-7.5	0.0	13.0	14,000	>10,000						

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
TVH : Total Volatile Hydrocarbons (THVA field instrument)
ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. O_2/CO_2 measurements by field instrumentation.
2. Soil sample at VW-1 taken at a depth of 8 feet bgs.
3. Benzene, Toluene, Ethylbenzene, and Total xylenes by EPA Method 8020.

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Table 3.15
INFLUENCE OF AIR INJECTION ON OXYGEN LEVELS
Building 2035
Fairchild AFB, Washington

Well No.- depth	Distance from VW-1 (ft)	Air Permeability Test Inital O_2 (%)	Air Permeability Test Final O_2 (%)
VMP1-5	10	10.2	9.0
VMP1-7.5	10	10.5	9.2
VMP2-5	16	6.9	4.5
VMP2-7.5	16	0.0	2.0
VMP3-5	33	6.5	1.0
VMP3-7.5	33	0.0	1.5

NOTES

Air Permeability Test lasting 20 hours performed on October 19-20, 1993.

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pathway for the injected air away from the VMPs. Based on the measured pressure response, which is an indicator of long-term oxygen transport, it is anticipated that the radius of oxygen influence for the extended pilot test will be approximately 30 to 50 feet from VW-1 (see Figure D.20); however, this estimate may be biased high because it is based on pressure responses of such low magnitude. The effective treatment radius for the extended pilot test will be better defined by monitoring the oxygen and contaminated soil-gas levels during the extended pilot test at the site.

3.5.4 *In Situ* Respiration Rates

An ISR test was conducted at Building 2035 between 20 and 22 October 1993 according to protocol document procedures. Air (20.8 percent oxygen) was injected at a rate of approximately 1 scfm into VW-1 and three VMP screened intervals (VMP1-7.5, VMP2-7.5, and VMP3-7.5) for 21 hours in order to oxygenate surrounding soils. After air injection was ceased, oxygen, carbon dioxide, and TVH levels in all VMP screened intervals (including those without air injection) were measured in soil gas for the following 29 hours. The results of the ISR test for Building 2035 are presented on Figures E.24 to E.30.

Results from the ISR test indicate that the VW and all of the VMP screened intervals had hydrocarbon contamination and active microorganism populations. The oxygen-utilization rates measured at the site were moderate, ranging from approximately 0.11% per hour at VMP2-5 to approximately 0.70% per hour at VMP3-7.5.

The air injected into the VMPs during the ISR test was a 4-percent helium mixture in air. The helium is used both as a tracer gas and to evaluate the effectiveness of the bentonite seals in the VW and VMPs. No appreciable loss of helium occurred at any VMPs where helium was injected between the end of injection and the final ISR readings taken after 29 hours of monitoring. Therefore, most of the oxygen loss observed during the ISR test was a result of bacterial respiration and not a result of either faulty well construction or overpurging of the VMPs during sampling.

Helium was also monitored at VMPs where air injection did not occur and at VW-1. Detection of helium at these points provides some evidence that significant volumes of soil were aerated by the 1 scfm pumps and consistent helium levels at these points over time indicates that decreasing oxygen levels in extracted soil-gas are due to respiration.

Based on the measured oxygen-utilization rates and the laboratory analyses presented in Section 2.7, an estimated 350 to 3,200 mg of fuel per kg of soil can be biodegraded each year at this site. The lower estimate reflects the slower oxygen-utilization rate measured at VMP2-5, while the higher estimate reflects the high oxygen-utilization rate measured at VMP3-7.5. The biodegradation rate estimates are based on calculated air-filled porosities and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Methods of calculation followed the procedures in the protocol document and are detailed in Appendix F.

Additional respiration testing at 6 months and one year following installation of the extended (one-year) pilot test system, and soil sampling one year following installation,

will better define the long-term biodegradation rates. Table 3.16 summarizes the data from the initial pilot test at Building 2035.

3.5.5 Potential Air Emissions

Air samples were taken at the ground surface at the Building 2035 site before and during air injection in order to evaluate the potential for discharge of petroleum hydrocarbons to the atmosphere resulting from subsurface air injection. The results indicate that no significant increase in either TVH or BTEX levels above those found prior to air injection at the site are expected to occur during the extended (one-year) pilot test.

Five surface measurement points were located radially around the injection well (VW-1) and at distances expected to be under the influence of air injection. Three of the surface measurement points were arranged around VW-1 roughly 120 degrees apart and located at a distance of 11 feet from VW-1. The remaining two measurement points were spaced at 22 and 33 feet from VW-1 in order to characterize the radial extent of any emissions. The air injection flow rate was approximately 18 scfm. Samples were collected as described in Section 2.2.

Results from the THVA were recorded in the field notebook and are shown in Table 3.17. In order to determine the TVH-jf and BTEX content of potential emissions, two surface air samples were collected for laboratory analysis, one prior to air injection and one during air injection (4 hours after initiation of injection) at the same location (SPT2), located 12 feet from VW-1. Results of the laboratory analysis for the two samples were summarized in Table 2.5.

Using very conservative assumptions that the hydrocarbon emission rates do not decrease over time and that the emission rates for the surface points nearest the injection well apply throughout the entire radius of influence, the potential total hydrocarbon emissions are estimated at 0.027 lbs/hr (240 lbs/yr). Because no benzene emissions were detected, potential benzene emissions are expected to be negligible.

These levels are significantly below the requirements set forth by the Washington Department of Ecology for small quantity emissions in WAC 173-460-080 for benzene (Class A pollutant) and total hydrocarbons (Class B pollutant). The long-term potential for air emissions during the extended (one-year) pilot test is also very low since the initial air injection probably displaced the highest concentrations of volatiles from the soil and the concentrations typically decrease with continued air injection. In addition, any accumulated petroleum hydrocarbon vapors in the pore space will be biodegraded as they move horizontally through the soil.

3.6 Background Wells

Initial soil-gas chemistry was measured in the two background wells on 2 November 1993. The VMPs were purged until oxygen levels had stabilized, and then initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers as described in the protocol document. The initial soil-gas chemistry measured at the background wells is summarized in Table 3.18.

Table 3.16
PILOT TEST DATA SUMMARY
Building 2035
Fairchild AFB, Washington

WELL No.-DEPTH	Soil Type	Laboratory Analytical Results		Air Permeability Test				*In Situ* Respiration Test					Calculated Biodegradation Rate
				Initial Soil Gas		Final Soil Gas	Air Perm.	Initial Soil Gas		Final Soil Gas		O_2 Util. Rate	
		TRPH (mg/kg)	TVH-jf (ppmv)	O_2 (%)	CO_2 (%)	O_2 (%)	k (darcy)	O_2 (%)	He (%)	O_2 (%)	He (%)	k_o (%/hr)	K_b (mg fuel/kg soil/yr)
VW1-(5-10) •	silty SAND	140	17,000	5.5	9.5	20.8	---	20.5	2.8	9.0	2.5	0.39	1,700
VMP1-5	silty SAND			10.2	4.9	9.0	17	20.5	2.4	14.5	1.9	0.22	690
VMP1-7.5 •	clayey SILT	66	14,000	10.5	5.1	9.2	19	20.5	2.6	13.9	1.5	0.23	750
VMP2-5	silty SAND			6.9	9.0	4.5	17	11.0	3.2	4.8	1.3	0.11	350
VMP2-7.5 •	silty SAND	32		0.0	10.7	2.0	19	20.5	3.2	0.8	2.0	0.54	1,400
VMP3-5	silty SAND			6.5	9.0	1.0	17	15.8	3.5	4.5	1.9	0.36	1,100
VMP3-7.5 •	SAND		14,000	0.0	13.0	1.5	19	20.5	3.4	0.5	2.5	0.70	3,200

LEGEND

TRPH : Total Recoverable Petroleum Hydrocarbons (EPA 418.1)
TVH-jf : Total Volatile Hydrocarbons as jet fuel (EPA TO-3)
• : VMP used for air injection during ISR test.

ND : not detected
mg/kg : milligrams per kilogram
ppmv : parts per million by volume

NOTES

1. VW-1 soil sample collected from 8 ft bgs.
2. Air Permeability Test conducted for 20 hrs at air injection rate of 18 scfm.
3. *In Situ* Respiration Test: air injection at selected VMPs for 21 hrs at 1.1 scfm; O_2 /CO_2 /TVH measurements taken for 29 hrs following injection.
4. Soil Temperature: 57.8 °F at VMP1-5; 58.2 °F at VMP1-7.5.

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Table 3.17
SURFACE AIR EMISSIONS
Buliding 2035
Fairchild AFB, Washington

Location	Distance from VW-1 (ft)	Prior to Air Injection	During Air Injection [1]
		TVH concentrations in ppmv	
SPT1	11	0	0
SPT2	11	28	0
SPT3	11	0	17
SPT4	22	0	20
SPT5	33	0	12

LEGEND
TVH :Total Volatile Hydrocarbons (THVA field instrument)
ppmv :parts per million by volume
[1] :Sample collection begun approximately 4 hours after start of injection

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Table 3.18
INITIAL CONDITIONS
Background Wells
Fairchild AFB, Washington

Well No.- depth	O_2 (%)	CO_2 (%)	TVH (ppmv)
VMPB1-5	17.0	2.2	65
VMPB1-7.5	17.0	2.2	50
VMPB2-3	20.0	0.8	45
VMPB2-5.5	20.0	0.8	35

NOTES
TVH :Total Volatile Hydrocarbons (THVA field instrument) Readings taken on November 3, 1993.

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Because the oxygen levels in VMP-B1 at 5 and 7.5 feet bgs were below 18%, a background well respiration test is required at VMP-B1 according to protocol document procedures. No background test is required at VMP-B2. An ISR test at VMP-B1 will be conducted during the six-month ISR tests at the bioventing sites in order to perform any necessary correction to oxygen-utilization rates. Although it cannot be assumed that no inorganic or natural carbon sources contributed to oxygen uptake during the ISR tests described in Section 3.0, the readings from VMP-B1 indicate that any oxygen uptake contributable to inorganic or natural carbon sources is probably minimal.

3.7 Recommendations

Initial bioventing pilot tests at all sites indicate that oxygen has been depleted in the contaminated soils and air injection is an effective method of increasing aerobic biodegradation of fuel contamination in the soil. The Air Force Center for Environmental Excellence (AFCEE) has recommended that air injection be implemented at each site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing soil temperatures on fuel biodegradation rates.

A small, 1.0-HP Gast™ regenerative blower (model R4) has been installed at each site to continue air injection for a one year period. In September 1994, ES personnel will return to each site to conduct a second respiration test (six-month test). In March 1995, a final respiration test will be conducted and soil and soil-gas samples will be collected from each site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on results presented by ES for the first year of pilot-scale bioventing, AFCEE will recommend one of two options for each site:

1. Upgrade, if necessary, and continue operation of the bioventing system for full-scale remediation of the site.

2. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and VMPs.

4.0 REFERENCES

Hinchee et al. 1992, Test Plan and Technical Protocol for a Field Treatability Test for Bioventing, U.S. Air Force Center for Environmental Excellence (AFCEE). January

U.S. Environmental Protection Agency (USEPA) 1986, Measurement of Gaseous Emission Rates from Land Surface Using an Emission Isolation Flux Chamber: User's Guide, EPA/600/8-86/008, February